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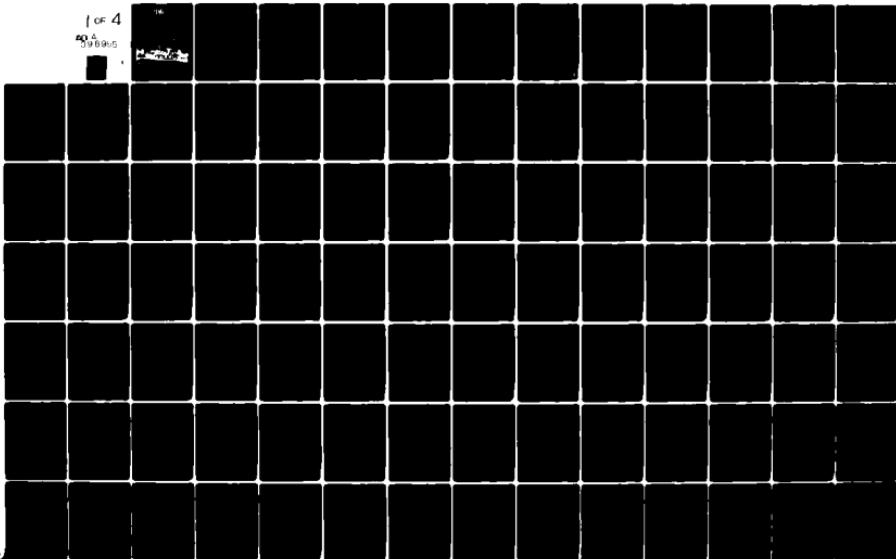
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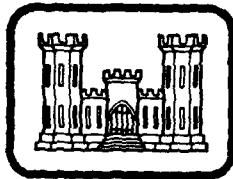
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TECHNICAL REPORT EL-81-1



PROCEDURAL GUIDE FOR DESIGNATION SURVEYS OF OCEAN DREDGED MATERIAL DISPOSAL SITES

by

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January 1981
Final Report

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1. The Technical Report transmitted herewith was developed as part of the Regulatory Criteria Development Research within the Dredging Operations Technical Support Program at the Waterways Experiment Station. The report was developed as part of the continuing work in support of the Corps of Engineers' (CE) regulatory program for the disposal of dredged material.

2. The report was developed to provide technical guidance for the CE Districts on conduct of site designation surveys for the preparation of Environmental Impact Statements to be used in designating ocean disposal sites for the dumping of dredged material under Section 103 of the Marine Protection Research and Sanctuaries Act of 1972. The guide is intended for two distinct groups of users. One will be CE personnel responsible for the survey work, who must understand the preparation of scopes of work, the review of proposals, and the evaluation of the results of the surveys. The other group will be scientists and technicians who have been contracted to actually carry out the surveys. The needs of both groups have been addressed in the guide.

3. The objectives of the guide are to provide the following for both user groups.

a. A description and tabulation of general characteristics of the historically used ocean disposal sites for dredged material.

b. To describe basic oceanographic processes occurring at these sites.

c. To discuss the basis for selection and location of sampling stations and the parameters to be measured at those stations.

d. To describe the actual conduct of the field sampling and procedures to be followed in the laboratory analysis of those samples.

e. To describe guidance on data processing and interpretation.

All these points are discussed in the context of compiling data needed

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for the preparation of an EIS on the designation of a particular dump site for continued use.

4. The sampling program described herein is intended to provide a data base descriptive of the site and characterize it sufficiently for preparation of an acceptable EIS. An equally important purpose is to provide a data base for establishing a meaningful monitoring program of the dump site on a continuing basis. Both objectives have influenced the content and format of the report.

5. The contents of this report will be particularly useful to those CE Districts conducting ocean disposal of dredged material and will aid markedly in the process of designating the sites for continuing use and in monitoring those sites should this be deemed necessary under the ocean disposal criteria.

F. R. Brown

F. R. BROWN
Engineer
Acting Director

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This procedural guide has been prepared to meet the needs of the Corps of Engineers, the Environmental Protection Agency, and ocean scientists who have been or will be called upon to carry out site surveys for the designation of dredged material disposal sites in the marine environment. Some of the guide's basic purposes are to detail what oceanographic parameters are to be studied, and to stipulate how to collect samples in the field and to analyze them in the laboratory. Another major goal of the guide is to clarify the role of the (Continued)				

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20. ABSTRACT (Continued).

monitoring program that may be instituted at each site pursuant to final designation and to relate its content to the original ocean survey.

Because the scientific content of the surveys is related in part to physical characteristics of the sites, the specifications of existing U. S. dredged material disposal sites, such as size, depth of water, and distance from shore, and their distribution among coastal Corps Districts are discussed in the first three chapters. Here also there is a brief discussion of the common features of the oceanography of the U. S. continental shelf because over 80 percent of all existing marine sites are located on the shelf. A substantial part of the guide is then devoted to the selection of oceanographic variables to be measured in the field, along with the rationale for placement of sampling stations. At this point also, the reader will find guidance in the selection of sampling gear and how to use it effectively at the selected stations. The following chapter is devoted to a detailed discussion of the preferred methods of sample analysis, covering biological, chemical, geological, and physical methodologies. The final part of the body of the guide is devoted to suggestions on effective presentation of the field and laboratory data generated by the survey. Because this guide can be expected to be used for some years to come, a few advanced sampling parameters not now in common usage--such as metabolic enzyme assessment of impacts, application of the adenylate energy charge system, and analysis of meiofaunal communities--have been included in the guide as purely optional entities.

Following an extensive citation of literature, the reader will find three appendices. The first provides a survey routine that a chief scientist or party chief may find useful in achieving a successful and efficient survey. The second presents time-and-cost estimates for an average survey that the environmental manager may find useful. Obviously costs are subject to change in time and will vary among geographic regions as well as with the depth and size of the sites to be surveyed. Nevertheless, the relative costs of measuring particular variables will very likely remain more or less constant. The third appendix lists the major suppliers of sampling gear mentioned in the guide.

In addition to the quite detailed Table of Contents, an alphabetical index of topics is presented at the end of the guide for the users' convenience in locating topics covered in the guide.

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PREFACE

This study was conducted by the TerEco Corporation, College Station, Texas and performed under Contract No. DACW39-78-C-0097, as amended, entitled "Development of a Procedural Guide for Designation or Assessment Surveys of Ocean Disposal Sites for Dredged Material Disposal," dated 28 September 1979, between the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, and the TerEco Corporation. The Dredging Operations Technical Support Program is sponsored by the Office, Chief of Engineers, U. S. Army, Washington, D. C., and is under the purview of the WES.

The research was conducted by and under the supervision of Dr. Willis E. Pequegnat, who wrote the Summary Guide, Chapters 1, 4, and 8, and Appendices A and B. Dr. Linda H. Pequegnat coordinated the project and edited the entire report. Dr. Bela M. James wrote Chapter 6 and contributed to other parts; Dr. F. A. Kennedy wrote Chapters 2 and 3; Dr. Roger R. Fay wrote Chapter 5; and Mr. Alan D. Fredericks wrote Chapter 7. The material for Appendix C was prepared by Interstate Electronics Corporation. Mr. Fain Hubbard prepared the illustrative materials, and Ms. Cynthia Kubicek and Ms. Cindy Berbulas assisted in manuscript finalizations. The advice of Dr. David D. Smith of David D. Smith and Associates, La Jolla, California, on the report and his assistance in the preparation of the proposal are gratefully acknowledged.

The study was managed by Dr. Richard K. Peddicord, EL, WES, and under the general supervision of Dr. John Harrison, Chief, EL.

Commanders and Directors of the WES during the conduct of this study and the preparation and publication of this report were COL John L. Cannon, CE, and COL Nelson P. Conover, CE. Technical Director was Mr. Fred R. Brown.

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SUMMARY GUIDE

This summary guide is designed to permit the reader to quickly identify where in the procedural guide he may find answers to general questions about the recommended ocean survey plan. A much more detailed guide is contained in the Alphabetical Index of Topics located at the end of the report.

PART I. INTRODUCTORY SECTION

Chapter I. Introduction

Chapter II. Grouping of Sites by Physical Characteristics

Chapter III. Analysis of Sites by Districts

Chapter I is much more than a routine introduction, for it is here that one will find not only the way the recommended survey plan has been molded to meet objectives (page 10) and to conform with applicable regulations and legislation (page 2) but also the philosophical considerations (page 12) that underlie the selection of the oceanographic parameters to be measured. Because most of the U. S. dredged material (DM) disposal sites are situated on continental or insular shelves (page 20) or, less frequently, on the continental slope (page 32), some relevant features of these subdivisions of the ocean environment are presented to explain the inclusion or exclusion of certain variables from the sampling program. All U. S. continental shelves share common features, making it possible to infer some conditions in geographic areas where the data base may be limited. For instance, there is a high degree of similarity in regard to the general pattern of long-shore currents and inshore circulation of ocean waters on the inner continental shelves at depths where the majority of DM disposal sites are located (see Chapter II). The same is generally true of the biological components, not to the species level, but in regard to the ecological types found.

Limited discussion of a suggested approach to monitoring surveys is included in the guide at several points. It is emphasized here and elsewhere that some components of the survey plan presented in the guide are labeled optional, primarily because they are not in general use in technical laboratories. They are discussed in the guide because TerEco believes that they can enhance the value of both designation and monitoring surveys by answering questions that are untouched by some more familiar sampling procedures. For example, it may be important to determine whether or not the presence of a measured amount of a toxicant in one of its metabolic pools is stressing an organism to the point of affecting its general welfare and reproductive capacity. An approach to this determination can be provided by analysis of the adenylate energy charge system. The energy charge and metabolic enzyme analysis, as well as meiofaunal studies, are offered as significant options in this guide. If a District chooses to include these and other advanced optional items in their surveys, the techniques for carrying them out are discussed in Chapters IV, VI, and VII.

The information in Chapter II deals with those characteristics of the 130 ocean dredged material disposal sites presently in existence that have helped shape the survey plan contained in Chapter IV. Data presented here on size, depth, and distance from shore (page 38) will provide some guidance to those who will determine the location and characteristics of new DM disposal sites. One will find in this chapter a discussion of the common features of existing sites that permit their organization into meaningful groups and a simplification of the survey plan (page 45). Then, in Chapter III, one can find how the 130 existing DM disposal sites are distributed among the Corps Districts having ocean sites (page 52).

PART 2. THE SAMPLING PROGRAM

Chapter IV. Selection and Elimination of Variables to be Measured in the Field.

Chapter V. Sampling Stations

Chapter VI. Implementation of the Sampling Program

There are three chapters in Part 2, and each is devoted to a thorough analysis of one phase of the sampling program. For instance, in Chapter IV, there is a discussion of what parameters should and should not be sampled and why the decisions were made (pages 77, 87, and 88). Parameters of the water column begin on page 90. Sediment parameters are discussed on page 94; biotai sampling begins on page 100; and other features including bioaccumulation and in situ bioassays begin on page 105.

Chapter V (page 111) provides flexible guidelines that may be used to lay out the numbers and locations of sampling stations within the site and contiguous areas.

Finally, in Chapter VI (page 130), after the variables and stations are decided upon, one will find a detailed discussion of the requirements for carrying out a solid sampling program. Vessel needs (page 130), gear requirements (page 131), benthic sampling reeds (page 133), and the use of equipment (page 138) are but a few of the topics covered here.

PART 3. LABORATORY AND INTERPRETIVE ANALYSES

Chapter VII. Laboratory Analysis of Field Samples

Chapter VIII. Presentation of Laboratory and Field Data

Part 3 is devoted to discussion of procedures for analyzing samples taken from the water column and sediment bed and to the presentation and interpretation of such data. Water column analyses, beginning on page 163, include, in order, trace metals, chlorinated hydrocarbons,

high molecular weight hydrocarbons, and total suspended solids. The benthic analyses, beginning on page 169, include, in order, grain size analysis, sediment trace metals, chlorinated hydrocarbons, total organic carbon, and the benthic biota. In addition, beginning on page 194, procedures are given for the analysis of metabolic enzymes and the adenylate energy charge.

Collecting field samples and analyzing them in the laboratory are only a part of preparing a meaningful environmental assessment. An equally important part is the organization, presentation, and interpretation of the data in a comprehensible manner. The use of graphs is encouraged for presentation of such water column parameters as salinity (page 207), temperature, and dissolved oxygen. The same is true for much of the sediment data (page 215). The analysis of biological data is more complex and usually requires a more inclusive statistical treatment than such conservative properties as salinity. Even so, the statistical techniques offered here, beginning on page 224, are meant to be advisory only. Other more sophisticated statistical techniques can be found in any one of several college textbooks of statistics.

Finally, beginning on page 251, there is a discussion of the application of some water quality criteria to data interpretation.

PART 4. LITERATURE CITED

PART 5. OPERATIONAL, COST, AND EQUIPMENT APPENDICES

Appendix A. Chief Scientist's Guide for At-Sea Operations

Appendix B. Basis for Estimates of Survey Costs

Appendix C. List of Equipment Suppliers

Appendix D. Alphabetical Index of Topics

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI)
UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
acres	4046.873	square meters
cubic yards	0.7645549	cubic meters
fathoms	1.8288	meters
feet	0.3048	meters
feet per mile	0.1894	meters per kilometer
gallons (U.S. liquid)	3.785412	cubic decimeters
inches	25.4	millimeters
knots (international)	0.5144444	meters per second
miles (U.S. nautical)	1.852	kilometers
miles (U.S. statute)	1.609347	kilometers
miles (U.S. statute) per hour	1.609347	kilometers per hour
ounces (mass)	28.34952	grams
pounds (force)	4.448222	newtons
pounds (mass)	0.4535924	kilograms
square feet	0.09290304	square meters
square miles (U.S. nautical)	3.429904	square kilometers
tons (2000 lb mass)	907.1847	kilograms

PART 1. INTRODUCTORY SECTION

I. INTRODUCTION

WHY A PROCEDURAL GUIDE IS NEEDED: FINAL SITE DESIGNATION REQUIRES
AN ENVIRONMENTAL ASSESSMENT

This procedural guide has been prepared primarily to meet the needs of the Corps of Engineers (CE), the Environmental Protection Agency (EPA), and selected ocean scientists who have been or will be called upon to deal with site surveys for the designation of both interim and new sites for the disposal of dredged material (DM) into the marine environment. With minor exceptions, the disposal of dredged material into the ocean can be done only at approved disposal sites. At present there are 130 such sites in U.S. marine waters, of which 127 were designated in 1977 and three in 1978 as interim disposal sites by EPA. These sites must receive final designation if they are to be used in subsequent years. But before final designation can be conferred, an Environmental Assessment (EA) and in many cases an Environmental Impact Statement (EIS) must be prepared for and approved by EPA for each site or for each group of generically related sites. Prior to preparation of an EA, special oceanographic surveys of many of the sites and their environs will very likely have to be carried out. Thus, one of the basic purposes of this guide is to present the scientific aspects of such surveys, including selection of the oceanographic parameters to be measured and how to carry out the measurements in the field and their analysis in the laboratory. The other major goal of the guide is to clarify the role of the monitoring program that may be instituted at each site pursuant to final designation and to relate its content to the original ocean survey.

LEGAL AND REGULATORY BASIS FOR EA REQUIREMENT

EARLY LEGISLATION

Federal legislation controlling waste disposal in the marine environment began with the Rivers and Harbors Act of 1899. For a long period following that enactment, control of disposal of dredged material was vested in the Corps of Engineers. The principal criterion for issuance of disposal permits was simply whether or not hazards to navigation or other impediments to transportation would be created.

In 1958 Congress passed the Fish and Wildlife Coordination Act. It attempted to prevent the disturbance or destruction of aquatic nursery and feeding areas caused by dredging or fill activities. It required consultation with applicable state agencies and the United States Fish and Wildlife Service prior to any environmental alteration subject to Federal permits.

RECENT NATIONAL LEGISLATION

Public Law 92-532

In 1970 the Council on Environmental Quality issued a report on ocean disposal that carried certain recommendations that were incorporated by Congress into the Marine Protection, Research, and Sanctuaries Act of 1972 (MPRSA; PL 92-532) that regulates the disposal of all wastes into ocean waters.

Issuance of Regulations and Criteria Governing Ocean Dumping

Disposal of dredged material from vessels at sea is permitted by the Corps of Engineers under the provisions of Section 103 of MPRSA, but permits are granted only under criteria that EPA established in accordance with Section 102(a). The final Revision of the Regulations

and Criteria governing ocean dumping was published by EPA in Part VI of the 11 January 1977 issue of the Federal Register. Applications and authorizations for dredged material disposal permits are evaluated by the Corps of Engineers in accordance with the criteria for evaluating environmental impacts set forth in Part 227 of the Regulations and Criteria, as follows:

The disposal of dredged material will present

- a. No unacceptable adverse effects on human health and no significant damage to the resources of the marine environment.
- b. No unacceptable adverse effect on the marine ecosystem.
- c. No unacceptable adverse, persistent, or permanent effects due to the dumping of the particular volumes or concentrations of these materials.
- d. No unacceptable adverse effect on the ocean for other uses as a result of direct environmental impact.

These provisions deal with complicated issues, and decisions based upon them must be for the most part judgmental. For instance, few people other than marine specialists are familiar with even the components of the simplest marine ecosystem, let alone with how the system works and what it can tolerate without suffering an "unacceptable adverse effect." Accordingly, the marine manager is well advised to consult with experts on his staff or drawn from outside to interpret the application of data drawn from ocean surveys.

Selection and Designation of Disposal Sites

The designation of dredged material disposal sites in the ocean will be executed by EPA or CE and will be based on

Environmental studies of each site, and on historical knowledge of the impact of dredged material disposal on areas similar to such sites in physical, chemical, and biological characteristics (Regulations and Criteria, Part 228.4).

The results of these studies will be used to prepare an EA and in some cases an EIS. An important provision regarding the number of separate impact assessments a Corps District needs to prepare for final designation of disposal sites in its jurisdiction states

An environmental impact assessment for all sites within a particular geographic area may be prepared based on complete disposal site designation or evaluation studies on a typical site or sites in that area. In such cases, sufficient studies to demonstrate the generic similarity of all sites within such a geographic area will be conducted.

The establishment of generic similarity would depend upon related sediment beds, biota, and those other oceanographic parameters that would determine the fate of the dumped dredged material.

All studies for the evaluation of interim sites and potential selection of new dredged material disposal sites will be conducted in accordance with five general and eleven specific criteria.

General Criteria (40CFR 228.5). Ocean dredged material disposal sites shall be located

1. To minimize the interference of disposal activities in the marine environment.
2. So that temporary perturbations in water quality during the 4-hour period of initial mixing will be reduced to ambient levels before reaching shore or marine sanctuary or fishery.
3. And shall be of sufficiently limited size that effective monitoring of disposal activities can be carried out.
The appropriateness of the size (considered in relationship to the amount of dumping) of an interim site shall be part of the evaluation study for final designation.
4. And shall be abandoned if the site in question does not meet the general and specific criteria in favor of a new one that does.

5. Finally, when feasible, new ocean dumping sites should be located beyond (a) other such sites that have been used previously, and (b) beyond the outer edge of the continental shelf.

Specific Criteria (40CFR 228.6). The eleven specific criteria are organized here into three main categories, as follows:

Location (information needed to justify and evaluate proposed siting)

- (1) Geographic position, including depth of water, bottom topography, and distance from coast.
- (2) Location in relation to breeding, spawning, nursery, feeding, or passage areas of living resources, either larval or adult.
- (3) Location in relation to beaches and other amenity areas.
- (5) Location in regard to the feasibility of surveillance and monitoring.
- (8) Interference with shipping, fishing, recreation, mineral extraction, desalination, fish and shellfish culture, or areas of special scientific importance.
- (11) Existence at or in close proximity to the site of any significant natural or cultural features of historical importance.

Oceanographic Characteristics

- (6) Dispersal, horizontal transport, and vertical mixing characteristics of the area, including prevailing current direction and velocity.
- (9) The existing water quality and ecology of the site, as determined by available data or by trend assessment or baseline surveys.
- (10) Potentiality for the development or recruitment of nuisance species in the site.

Relationship to the Waste

- (4) Types and quantities of wastes proposed to be disposed of and proposed methods of release, including methods of packing.

- (7) Existence and effects of previous discharges and dumping in the area (including cumulative effects).

NATURE OF OCEAN SURVEYS OF DREDGED MATERIAL DISPOSAL SITES

OCEAN SURVEYS SUBJECT TO REASONABLE MODIFICATION

To assist in developing this guide, TerEco Corporation convened two workshops at which some 60 ocean scientists and Government personnel debated the oceanographic variables that should or should not be included in a site-designation survey. During the course of these workshops it became apparent that many participants believed that any survey dealing with ocean dumping had to include all of the items listed in the guidelines in Part 228.13 of the Regulations and Criteria on Ocean Dumping promulgated by EPA in the 11 January 1977 Federal Register. This, however, is not the case. There is a limitation of sorts in Part 228.1 (applicability) that is easily overlooked; it says

The criteria of this Part 228 are established pursuant to section 102 of the Act and apply to the evaluation of proposed ocean dumping under Title I of the Act. The criteria of this Part 228 deal with the evaluation of the proposed dumping of material in ocean waters in relation to continuing requirements for effective management of ocean disposal sites to prevent unreasonable degradation of the marine environment from all wastes being dumped in the ocean. This Part 228 is applicable to dredged material disposal sites only as specified in Parts 228.4(e), 228.9, and 228.12.

The underlining is TerEco's; the key words in the above are "applicable" and "only." Part 228.4(e) calls for environmental studies prior to final designation and requires that the selection of new sites shall follow the criteria that were listed above, but Part 228.12 states that the interim sites are not burdened by the criteria for size and usage given above. Moreover, wherever reference is made to the content of an ocean survey, the phrase "applicable requirements" is inserted.

Clearly this is a judgmental issue and one that provides for considerable latitude in formulating a survey program for dredged material disposal sites. It is obvious that it is desirable to have a high degree of uniformity in these surveys, thus the manual has another important function to perform.

OCEANOGRAPHIC CHARACTERIZATION OF THE SITE THROUGH THE BASELINE SURVEY

The thrust of the EAs and EISs for site designation relates to a thorough analysis of the impacts that may accompany the disposal process. In large measure, the physical extent of these impacts, both within and outside of the site, will depend upon the oceanographic nature of the site. Although in some instances sufficient data on an interim site may already exist from which an EIS can be prepared, it is anticipated that oceanographic surveys will have to be conducted at the majority of sites. It is visualized that these surveys will be carried out in a scientific manner, but it is clear that economic and time constraints mandate that they cannot be designed as esoteric scientific studies. Rather, they will be designed to fit very practical needs, producing data from which to characterize a site in terms of those particulars that are closely related to the impacts of dredged material disposal. Both qualitative and quantitative data will be appropriate for site characterization, but nothing of significance can be added to the survey's plan, unless the derived data can be related to impacts or impact reduction or can, as shall be discussed next, provide the basis for future monitoring of the effects of actual disposal at the site.

DATA BASE FOR A MONITORING EFFORT

The final designation of a marine dredged material disposal site carries with it the strong probability that the District Engineer will find it advantageous to monitor the site at appropriate intervals to ensure that unexpected deterioration of the site environs is not occurring. Monitoring efforts will be searching for unfavorable

trends. In order to detect such trends, if indeed any exist, it will be necessary to have baseline (bench mark) data for comparison. These data will have been gathered during the designation survey. It is emphasized here, however, that the monitoring survey will differ from the designation survey in several particulars.

In the first place, the monitoring survey must sample variables that can be quantified with a reasonable degree of accuracy. Even though a variable may be reported in numerical terms, such data may be worthless in a monitoring effort if the sampling gear and technique carry such a high built-in variance that there can be little confidence that two sets of data taken at the site have any meaning if they are the same or different. For instance, sampling of the epifauna with an otter trawl will produce data that are qualitative but not very quantitative simply because the size of the net aperture, if it is open at all, depends in part on the speed of tow. Such data are useful for site designation but not for the monitoring effort. A better approach to epifaunal sampling is by means of a fixed-aperture beam trawl, as discussed in Chapter IV.

The above consideration points up a second significant difference between a site designation and a monitoring survey: the latter will deal with the measurement of a smaller number of parameters. Thus, the selection of variables to be included in the monitoring study will depend upon analysis of important impacts and on knowledge of appropriate quantifiable parameters. The bottom line, so to speak, of the concern with impacts centers in the biological aspect of the environment. It is unlikely that dredged material will have any serious or lasting effect on temperature, salinity, dissolved oxygen, or even turbidity in the water column. Thus, although these parameters are quantifiable and excellent for site characterization, they are of no critical value for monitoring. On the other hand, there is a strong possibility that continued dumping will affect some organisms in

measurable ways. A parameter of particular concern today is bio-accumulation. The uptake of materials from the environment is a perfectly normal function and is of little concern when the compounds are utilized or broken down (metabolized) by the organism. When, however, the materials are not metabolized or discharged from the body but are stored unchanged in one or more of the organism's tissues, the accumulation takes on new importance, especially if the material is a toxic metal, polychlorinated biphenyl (PCB), organohalogen (i.e., chlorinated hydrocarbon), or petroleum hydrocarbon. Food webs in the marine environment are so little understood that even if bioaccumulation occurs in a seemingly unimportant species, it may prove to be the food of a species harvested by man. In such cases it is important to determine whether or not the presence of the toxicant in one of its metabolic pools is stressing the organism to the point of affecting its general welfare and reproductive capacity. An approach to this determination that is now used by Woods Hole Oceanographic Institution, TerEco Corporation, and some National Oceanic and Atmospheric Administration (NOAA) Laboratories, but, which is presented as an option survey item in this guide, employs an analysis of selected metabolic enzymes that respond to the presence of particular toxicants and reveal the presence or absence of stressful conditions. If a District chooses to include these in situ bioassay and bioaccumulation techniques in its survey plan, they will yield data that are applicable to both designation and monitoring surveys. The techniques for carrying them out are discussed in Chapters IV, VI, and VII.

PROBABLE USERS OF THE GUIDE

Throughout its preparation, the authors have been influenced by the belief that the guide will have two very different groups of users. One group will be personnel of the Corps of Engineers, particularly in Corps Districts, who must issue Requests for Proposals (RFPs) for survey work and must therefore understand the nature of a survey in order to prepare scopes of work and eventually evaluate proposals.

This understanding, which must be shared by EPA personnel, is also

necessary for sound interpretation and decision making on the basis of survey results. The other group will be those scientists and technicians who have been contracted with to carry out the surveys and analyze the data. Accordingly, the guide has been formulated to satisfy the requirements of both groups (for additional user groups, see Chapter IV).

OBJECTIVES OF THE GUIDE

It is to be expected that a procedural guide will have many objectives, most of which are reflected in the headings of the table of contents. As stated above, the guide is designed to meet the needs of two distinctly different groups of users; hence, the objectives stated here are the authors' understanding of the needs of the users.

- a. Describe and tabulate the general geographic location and physical characteristics of the 130 interim sites.
- b. Describe the physiographic and oceanographic dimensions of a model dredged material disposal site in the marine environment.
- c. Provide a synthesis of the basic oceanographic processes going on at and around this exemplar marine disposal site.
- d. Discuss the measurements and samples to be taken in a field survey of a disposal site that will yield the data needed for preparation of an EIS, relating the discussion to potential impacts.
- e. Recommend and describe the types of oceanographic equipment needed to carry out the measurements and sampling.
- f. Describe how to carry out the field sampling, noting why the measurement of some variables is deemed unnecessary, and how to process the samples in the field.

- g. Provide the basis for selecting the number and position of stations at which samples of each variable will be taken.
- h. Discuss the nature of the sites in each Corps District and recommend sampling programs.
- i. Describe procedures to be followed in the laboratory phases of the required analyses.
- j. Provide useful guides for processing the data and interpreting the significance of the findings.

GENERAL NATURE AND OCEANOGRAPHIC SETTING OF SITES

Its physical characteristics, including among other things its size, shape, and distance from shore, dictate the intensiveness of the field survey undertaken to characterize a site for designation. As is explicit in the specific criteria stated above, the fate or ultimate disposition of the dredged material dumped at a marine site will determine the full range of the impacts that are a foremost consideration in site evaluation. Because the ultimate disposition of the material depends upon the oceanographic characteristics of the region in which the site is located, it is felt that some general discussion of the setting of the majority of sites is appropriate here. A more specific discussion of oceanographic conditions occurring at the sites within Corps Districts will be undertaken in Chapter II.

PHYSICAL CHARACTERISTICS OF SITES

Most dredged material disposal sites are small. Some 82% are less than 2.0 n mi²* in area, and over half of these actually cover less

*A table of factors for converting U.S. customary units of measurement to metric (SI) units can be found on page xviii.

than 0.5 n mi². General Criterion No. 3 cited on page 4 limits the size of disposal sites to localize impacts and promote the relative simplicity of the site survey and feasibility of monitoring. Other factors that simplify survey sampling and thus reduce the time required to complete the study are proximity to shore and shallow depth. The bulk of the present marine dredged material sites are within five nautical miles of shore. Seventy percent are located in water less than 20 meters deep and only 15 percent are deeper than 90 meters. In several cases the center of the site is less than 3 meters deep, requiring that sampling be done from a relatively small vessel. The majority of sites are close to the sources of dredged material. This is even true of sites that are considerable distances offshore, as at the Mississippi River Gulf Outlet, because the sites are adjacent to and parallel with the dredged channel. It is quite likely that many new sites will have to be located farther offshore.

Proximity to shore, shallow depth, and small area facilitate the task of conducting oceanographic studies of the sites. Their shallow depth means that the water column is either uniform from top to bottom throughout the year or at most develops a two-layered system during the warm months. Shallow depth and proximity to shore also mean that the DM sites are influenced by wind and swell. Data on both of these factors are frequently available in the literature for the general areas where sites are located. Expensive and drawn out water-movement studies may be eliminated if enough data on the above factors are available and, regarding probable water movements, agreement can be reached among Corps, EPA, and marine scientists involved in survey plans.

SAMPLING PHILOSOPHY

RELEASE ZONE VS. EXTENDED IMPACT ZONE

One cannot establish or evaluate a sound sampling program without an understanding of the probable full oceanographic dimensions of the

site or sites to be sampled, and without a working knowledge of the oceanographic factors that determine the magnitude of these dimensions. In this section the authors propose to examine the concept of the extended impact zone, because it must be understood in order to justify the number and position of sampling stations. In a later section, the oceanographic systems involved shall be examined.

Definition of Extended Impact Zone

If dredged material is dumped on land, the environment of the disposal site may be thought of in terms of the site's specific location, topography, surface and subsurface geology, and drainage characteristics. For several reasons the marine disposal environment cannot be characterized so simply, nor can its effective location be pin-pointed so accurately. A land site is planar, having two dimensions, and in a legal sense so is the marine site. In actuality, however, the marine site is three-dimensional, comprised of the water column or pelagic component and the bottom or benthic component. These form an imaginary rectilinear column. To understand impacts one must consider that the marine site has the fourth dimension of time, because the dumped material takes longer or shorter periods of time to come to its initial rest on the bottom after having been discharged at or near the surface of the water. In practical terms, then, the release zone can be described easily in terms of coordinates of latitude and longitude (or Loran C lines), but it is not within the confines of these dimensions or even of the three-dimensional unit that much of the dredged material comes to rest -- even temporarily. Some of it, perhaps much of it, depending on the nature of the material, depth of water, and strength of current, will strike the bottom downstream of the release zone. TerEco personnel have come to call this downstream extension of the release zone the extended impact zone. It is an understanding of this zone and the processes that account for its location and size relative to the release zone that are essential to the evaluation of the effects of disposal at sea. As Pequegnat et al. (1978) have pointed out, the three conceptual components of the extended impact zone are its location in relation to the material being dumped, the hydrodynamics at and around the site, and its biodynamics or the

influence that certain organisms are exerting on the finer materials while they are still falling in the water column. In truth, it is the extended impact zone that should be of greatest interest and concern to the manager of the marine environment, because its position and size in relation to human amenities will indicate to him whether a release zone should or should not be moved in order to protect a valuable resource. The following paragraphs examine the oceanographic determinants of the extended impact zone.

Determinants of the Extended Impact Zone

Location in Relation to Nature of Dumped Material. If solid, dense material such as concrete is dropped from a surface ship at a position that can be called the release point (Figure 1), the material will sink rapidly through the water column and come to rest on the bottom in a position more or less directly below the surface vessel. In this case the disposed material will have only a transient effect in its path through the water and a more permanent effect upon the bottom surface where it comes to rest. Reciprocally, the water column will have little effect on the direct passage of the material to the bottom. In this case the extended impact zone is little more than a vertical projection of the release zone. If, however, more typical fine sediment-type dredged material is dumped in the release zone, oceanographic factors will exert substantial effects on the path of the water column transit and the material can come to rest upon the bottom in an area of variable size.

Hydrodynamics. If the material to be dumped includes a loose assortment of particle sizes ranging from pebbles through gravels, sands, silts, and clays, the extended impact zone is no longer a simple bottom projection of the release zone. Each particle tends to sink at a rate dependent upon its size (cross-sectional area) and its density relative to the densities of the water mass or masses through which it passes. Differential sinking rates in the plume will result

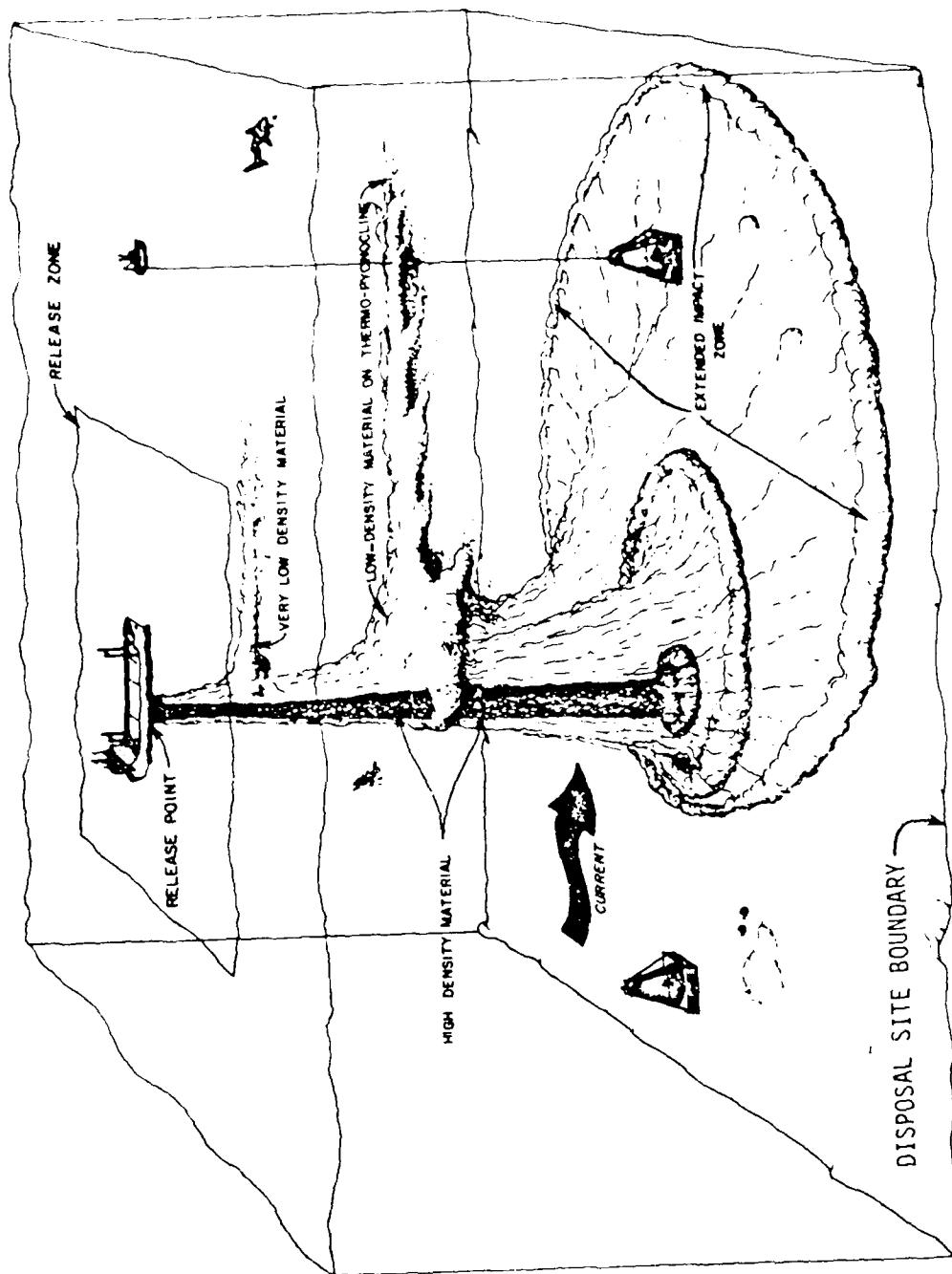


Figure 1. Schematic showing the extended impact zone (extended impact area on the bottom) and its probable relationship to the release zone of a dredged material disposal site during a hopper dredge discharge. The position of the release point, where the shipload is being discharged, can be changed by the District, from time to time to obtain uniform distribution of sediments.

in a sorting of particles. But many of the particles may adhere to one another and behave as larger particles. The sinking of the entire mass may create a vertical current, which sucks the smaller and less dense particles downward for some distance. Eventually, however, the size and density of each particle will largely determine its own rate of sinking. For a more complete description of the sinking of dredged material, see Pequegnat et al. (1978). Clearly, depth becomes a determiner of the characteristics of the extended impact zone because it allows a longer time for the dynamics of the water column to transport the particles.

As a result of density sorting and water mass movement, dredged material composed of different size classes of particles will spread over large areas of sea bottom in a graded series, with the larger and denser materials settling closer to the release zone. Progressively finer particles will be distributed in a graded fan, extending for varying distances downstream as it forms the extended impact zone (Figure 1). Meanwhile, other factors may be affecting the sinking material (Pequegnat et al. 1978, Wright 1978, Brandsma and Divoky 1976).

Biodynamics. As the disposed material spreads out at the thermopycnocline (see Chapter IV, p. 91, and Chapter VIII, p. 207) and finally settles to the bottom, some of the finest particles will interact with certain living organisms in the water column. Many species of phytoplankton and zooplankton produce mucus or other gelatinous substances to which the particles would readily adhere and form clumps of appreciable size. Even marine bacteria may well be involved in this process. Such aggregations do drag many organisms to the bottom, but this effect is localized. This process clears up turbid water by hastening the removal of finer particulates from the water column. In addition several zooplankton groups, such as copepod crustaceans, feed by filtering large volumes of water with bristle-bearing appendages which tends to concentrate finer materials into

larger compact fecal pellets, having faster sinking rates than the isolated particles.

OBJECTIVES OF THE SAMPLING PROGRAM

The sampling program of the field survey has been designed to fulfill two principal purposes. First, it is intended to yield data that are descriptive of the site and will thus characterize it sufficiently for preparation of an acceptable EA and/or EIS. Because historical data may be available for some parameters, care must be exercised in selecting those environmental variables that will be sampled and those that will not. The second purpose is to provide data that can be used as the basis for establishing a meaningful monitoring program that may be carried out after final designation of the disposal site has been achieved.

Site Characterization and EIS Preparation

Before either an interim or a new dredged material disposal site can receive final designation, an Environment Impact Statement may be prepared, reviewed, and approved by EPA. Because today's EIS must emphasize a thorough analysis of alternatives and of the real and potential impacts resulting from dredged material disposal, the EA on which the EIS is based should contain data on carefully selected oceanographic variables. Taken together the values should provide not only a descriptive characterization of the site and its environs but also a functional understanding of the fate of the dredged material at that site.

It is not appropriate at this juncture to present details of the recommended sampling program, for that will be done in Chapters IV and VI. Rather it is the authors' purpose here to establish the framework upon which the selection of variables to be surveyed and those not to be studied is based. The site surveys for interim or new sites are

not scientific studies, gathering knowledge for its own sake, and if interpretive use cannot be made of data, it should not be included in the survey. In other words, survey work should be carried out in a scientific manner, but the range of variables must be limited. For example, it is doubtful that a short-term study of currents by means of fixed current meter arrays would yield useful data. In fact, it could mislead one in making certain decisions as to the fate of disposed material, as discussed in Basco et al. (1974). If historical data of a longer term value are not available in the literature or technical reports, it is preferable at most of the sites to correlate water movements with long-term wind data for offshore areas. A final point is simply that a single storm might result in more transport of sediments than a persistent current.

Because most of the dredged material is relatively high density that will fall rapidly to the bottom, its transit time down the water column is too short to create appreciable impacts upon the pelagic biota. Moreover, since the water over the site will likely move out of the area in a short time, it seems that little useful information on impacts would be gained by this sampling. To sample at a given station after an interval of time would not ensure collecting impacted water and contained organisms. Both would have moved to a new undetermined position downstream. To ensure collecting impacted organisms after an interval of time would require employing some method of following the water mass. This is not to say that information on the pelagic biota is not a valuable component of site characterization, because it is. But it is hoped that such information can be obtained in published literature or various technical reports issued to or by the Corps District.

The main study emphasis should be on the benthic environment. It is there that any significant impacts will be registered, and it is there that sufficiently quantitative data can be collected as a basis for a future monitoring program.

Establishing the Sampling Stations

The number and position of sampling stations established at and around a disposal site must be sufficient to accomplish the following:

- a. Characterize the site oceanographically.
- b. Predict the nature and intensity of impacts that dredged material will have on the site's environs.
- c. Provide the basis for a monitoring program to test the validity of the predictions.

If the site receives final designation, it seems likely that previous disposals have not been judged to be unacceptably adverse by those persons who prepared the required EIS. Therefore, it may be assumed that future impacts have been predicted to be no less acceptable. The monitoring program is intended to see to it that no serious change in impacts has occurred since final designation.

To accomplish trend assessment, stations both inside and outside the site and both upstream and downstream of the site are necessary. The number of stations within the site will depend upon its size but will normally range from two for the smallest site to six in the largest. (More stations may be required when a valuable resource is present in the contiguous area.) In general there should be one or two sites upstream and one or two downstream, except in the case of deep sites where a third station should be added downstream. It can be expected that the larger the site the greater its radius and the greater its environmental influence on its contiguous area. Hence, the nearer upstream and downstream sites should be positioned at a distance equal to the site's radius ($\sim \frac{1}{2}$ n mi) and the other a diameter's distance from that (~ 1 n mi). The latter diameter's length can be used for locating a third station, if needed; see Figures 15 and 16, Chapter V (pages 119 and 125).

When a "critical area" exists in the vicinity of the disposal site (e.g., spawning grounds for commercially important species, beach or recreational area, etc.), then one or two sampling sites should be located between the disposal site and the critical area.

The reason for advising locating the sampling sites where recommended and advocating taking certain kinds of samples and leaving others out is based primarily upon oceanographic considerations. Since all but a few marine dredged material disposal sites are located on the continental shelf, the effort will be concentrated there.

THE CONTINENTAL SHELF

THE MOST USED AND MISUSED PART OF THE OCEAN

Even though the continental shelf underlies a scant 7.5% of the total area of the oceans and is flushed by only a small portion of their volume, much of man's utilization of the sea is largely confined to it. For the most part this is true of the disposal of wastes. Thus, with few exceptions, such as off Hawaii, Puerto Rico, Guam, and American Samoa, ocean dredged material disposal sites are located on the shelf's inner part. It is here also that a great harvest of finfish and shellfish is taken; it is here that quantities of petroleum and gas are extracted; it is here that sands, gravels, and some precious stones are mined; it is here that sports fishing, sailing, and other recreational pursuits occur off major and minor harbors; and, in the midst of it all, it is here that many wastes in addition to dredged material are effectively disposed of in substantial amounts.

The question inevitably arises in the minds of both managers of the ocean environment and environmentalists alike, how much waste can the waters and sediments of the shelf assimilate before damaging processes result? There may be no simple answer to the question, although it seems likely that it can take much more dredged material. But it is

evident that the crucial aspect of the problem is not really so much whether or not man should stop disposing of wastes on the shelf as it is how it is done in regard to the oceanographic characteristics of the shelf in general and its specific characteristics at a given site. In other words, this important area must be managed with understanding by representatives of all the users of the shelf. It is for this reason that each manager of dredged material disposal must have a working knowledge of the continental shelf in his area of concern.

OCEANOGRAPHY OF THE SHELF

The continental shelf is the submerged margin of a continent, and, by extension, it is also considered to include the shallow margins of oceanic islands. United States laws define the continental shelf as the seaward extension of the coast to a depth of 600 feet (100 fathoms or 183 m). It slopes seaward gradually from shore with an average drop of about 12 feet per mile. Its outer limit, the shelf break, is marked by an increase in gradient to about 264 feet per mile. This is the beginning of the continental slope that moves down to the deep-sea bottom. The shelf break generally occurs at some depth between 110 to 146 m.

The continental shelf varies considerably in width, ranging from a few miles off the west coast to as much as 135 or so nautical miles off parts of the gulf coast. One might think that these relatively narrow and shallow areas, over which only 0.1 percent of the ocean's waters lie, would be poor receptacles for wastes. But this is not the case, at least at the present time. The reason is simply that the shelf is a high-energy environment that is markedly affected by wave, swell, and strong currents of onshore, offshore, or longshore types. It is much more variable than the oceanic region on its seaward border.

Even though all of the marine environments are in potential continuity,

the sea is certainly not homogeneous. Nearshore waters are influenced by the continental climate; they are modified by the proximity of estuaries and coastal lagoons; they are freshened and nourished by runoff from streams; and their bottoms are not far removed from the sea surface. Proceeding away from shore the continental climate gives way to the maritime climate; the influence of estuaries, lagoons, and streams becomes less pronounced; and the depths become progressively greater until the abyssal plain is reached. These basic factors are reflected in the nature of the water columns and the bottom environments, which are subdivided into zones each of which is characterized by its own suite of temperature, salinity, turbidity, nutrients, current pattern, and sediment conditions. Some of the changes occur gradually while others are more abrupt. As the environments change with depth and distance from shore, so do the living systems that inhabit the environments. Such changes in environments and the biological systems they support must be taken into account in any consideration of the effects of the disposal of dredged material in the marine environment, because the effects will vary depending upon which systems receive the materials (Pequegnat et al. 1978).

Shelf Ecosystem

The nonliving components of these systems, which together with their living entities are called ecosystems, include the atmosphere above the water, the water column itself, and the floor of the sea.

Atmosphere

The atmosphere above the water is of primary importance to the present discussion because water mass movement is induced largely by the functional force of winds passing over the water surface. Wind-drawn currents play a major role in the horizontal spread of organisms and of many materials discharged at sea. Turbulence, involving vertical water movement, creates a mixing layer where wastes are diluted and

into which nutrients are brought from deeper waters into the lighted zone, especially in fall and winter, where photosynthesis takes place in late winter and spring. The wind creates waves that will move sediments far more effectively than currents. Because the orbital velocity of water under the crest of a wave reaches a higher value than that under the trough, there tends to be a shoreward movement of sediments (Figure 2). As an example, waves only one meter in height will have velocities that reach the threshold of sediment motion for coarse silts or even medium sand at water depths of 20 to 30 meters (Figures 3 and 4). In most places waves run up the beach at an angle, but their fallback is vertical (Figure 5). As a result longshore currents are produced which will transport sediment along the beach that was brought to shore by waves (Figure 6).

The temperature of the air also determines the temperature of the near-surface water, especially in coastal areas where the water is shallower. Sunlight, transmitted through the atmosphere, penetrates the water surface and supplies the radiant energy required for growth of minute marine plants called phytoplankton. Exchange of gases between the sea and the atmosphere also takes place at the air/sea interface. Thus it is, that the atmosphere is of paramount importance in regulating environmental conditions in the surface waters of the sea, and by so doing it is largely responsible for regional differentiation of coastal waters.

Light

The seasonal progression of the sun determines that greater amounts of heat and light will be received by the surface waters during late spring, summer, and early fall than during the winter, when the sun is more directly over the southern hemisphere. Much of the sunlight striking the sea surface is reflected back into the atmosphere, and that which does penetrate the sea surface is rapidly scattered and absorbed by water molecules and by smaller suspended particles. For

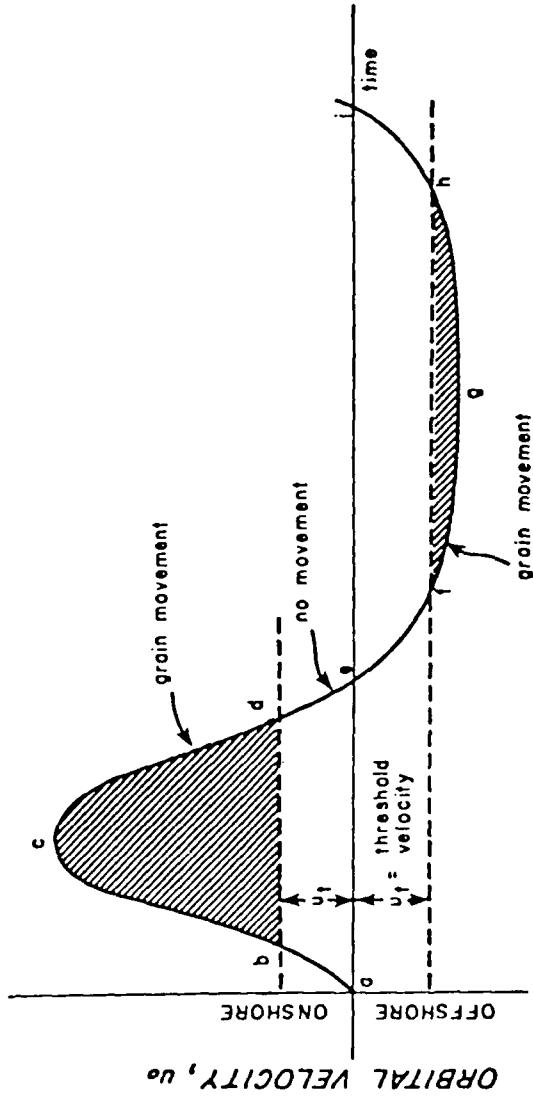


Figure 2. Sediment movement under a near-bottom wave orbital motion, the velocity at c under the wave crest reaching a much higher value than at g under the trough. This causes a net onshore movement of certain sediment sizes, the grain movement being represented by the cross-hatched areas. However, the degree of transport is not directly proportional to the areas of cross-hatching.

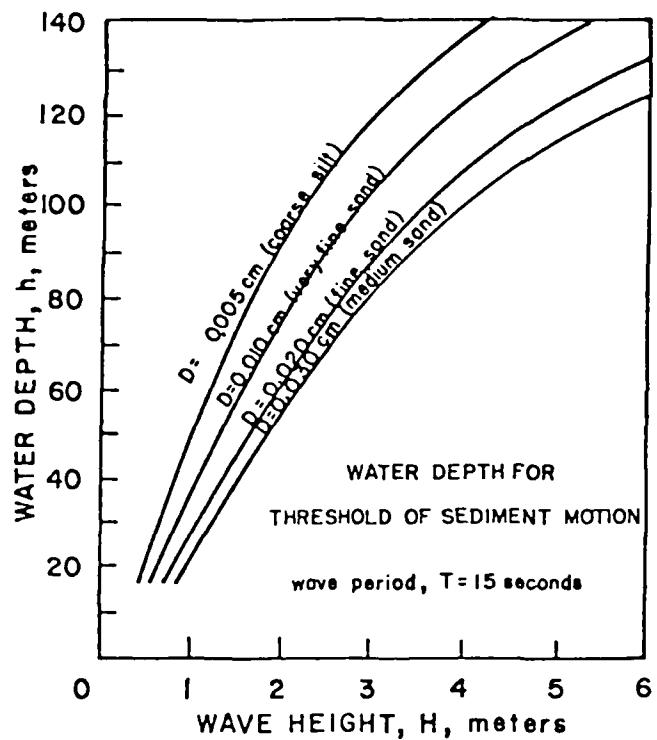


Figure 3. Expected water depth of sediment movement due to surface waves for period $T = 15$ seconds and a range of sediment grain sizes and wave heights.
 (Courtesy of Komar, P. D. and M. C. Miller. 1975.
 Sediment threshold under oscillatory waves. In:
 Proc. 14th Conf of Coastal Engrs. Amer. Soc. of
 Civil Engineers, New York, pp 756-775.)

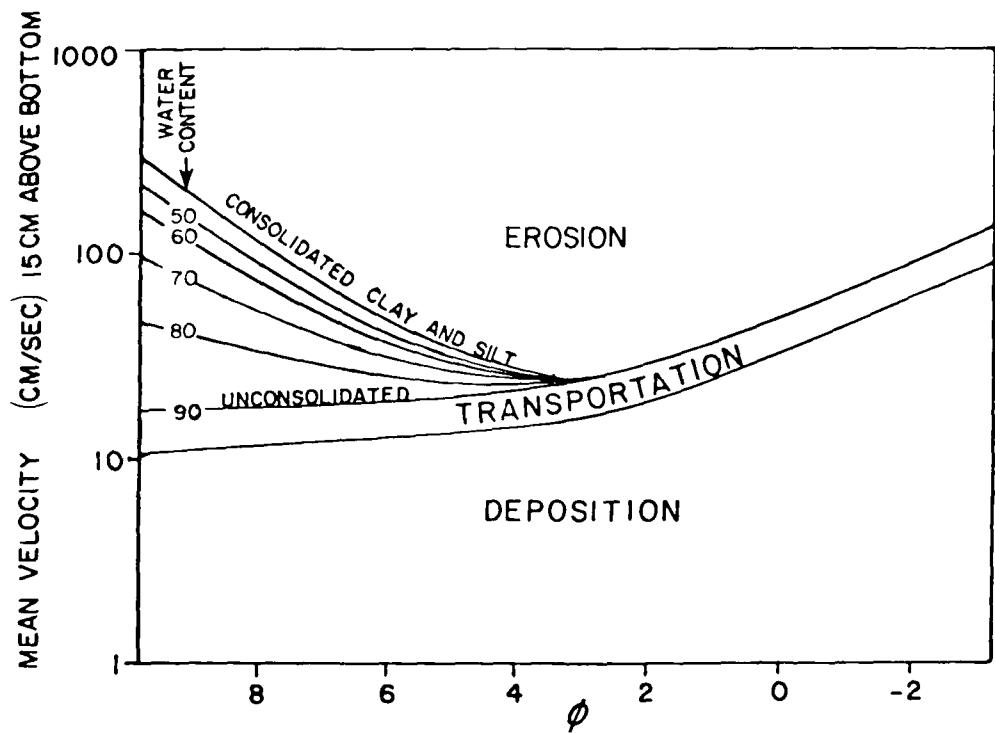


Figure 4. Current velocities required to transport particulate materials. (From Postma (1967), AAAS Pub. No. 83, pp 158-179. Copyright 1967 by the American Association for the Advancement of Science.)

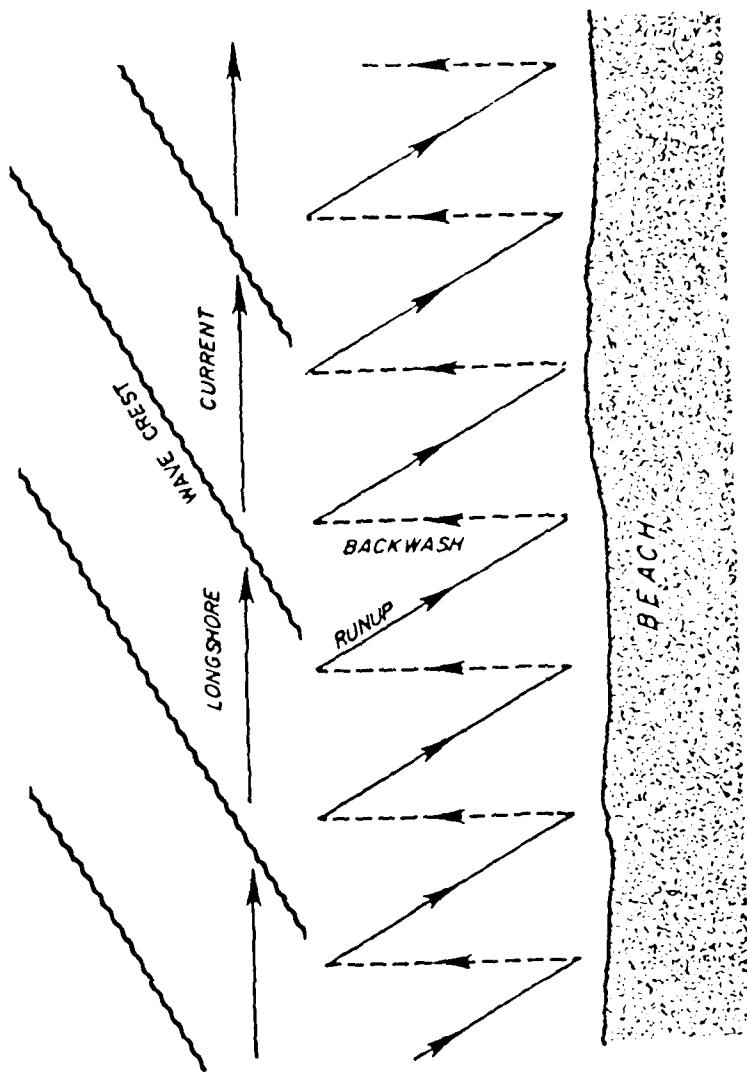


Figure 5. Graphic portrayal of how a train of waves approaching the shore at an angle can create a longshore current. Note the waves run up the beach at an angle, but the water falls back nearly perpendicular to the beachline. Dredged material that is brought to shore by bottom movements will be moved along the coast.

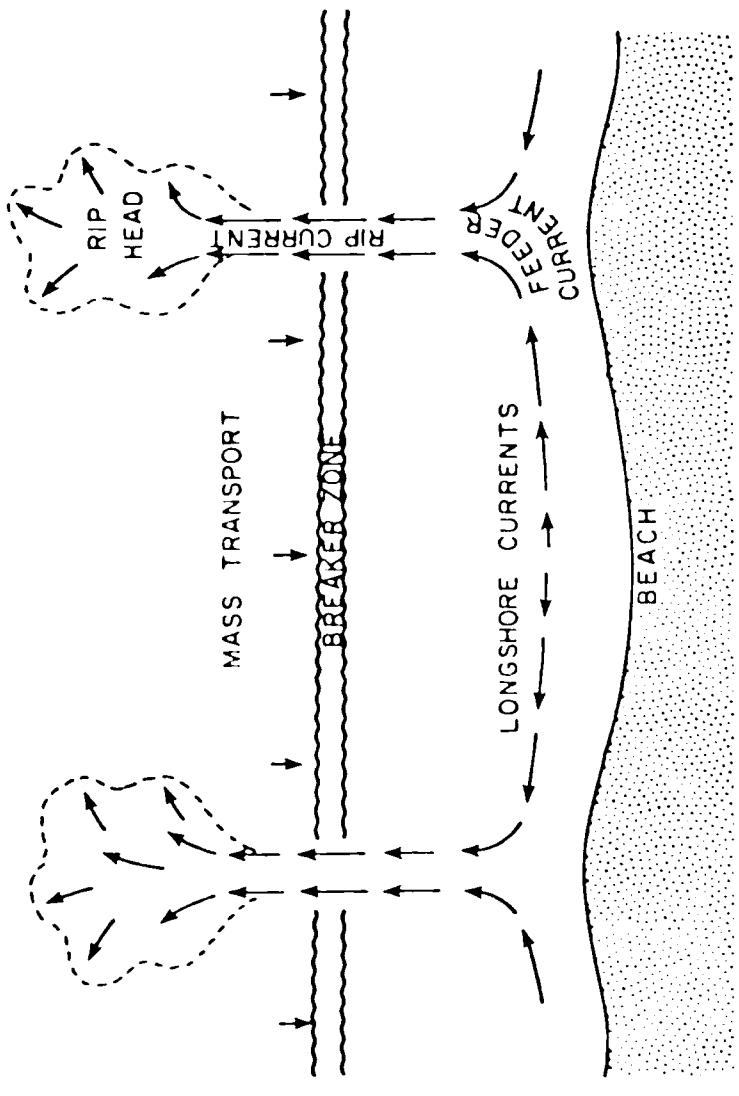


Figure 6. The nearshore cell circulation consisting of (1) feeder longshore currents, (2) rip currents, and (3) a slow mass transport returning water to the surf zone. (After Shepard and Inman (1950), Trans. Am. Geophys. Union, Vol 31, No. 4, pp 555-565, copyrighted by American Geophysical Union.)

these reasons, sunlight is attenuated in seawater by a logarithmic function of depth. Even in very clear ocean water about 55% of the incident radiation at the surface has been absorbed after penetrating to a depth of about 1 meter, and only 1% is left at some depth between 50 and 100 meters. In very turbid coastal waters 83% is gone in the first meter and only 1% remains at 5 meters depth. Phytoplankton growth, which is the basal component of the ecosystem, is limited by the quantity of light available for photosynthesis, and phytoplankton generally cannot carry on photosynthesis when the light level is less than 1% of the surface value. Therefore, the depth of the euphotic zone, which is the upper layer of the sea where light is sufficient to support photosynthesis, tends to be greater in the open sea than in more turbid coastal waters, greater in summer than in winter, and greater in tropical latitudes than in temperate or polar latitudes.

Temperature and Density

When the short-wave energy of the sun penetrates into the water, it is absorbed and causes the temperature of the sea to rise. As a result the surface waters may become sufficiently less dense than the deeper layers so that a condition of thermal stratification is established. Thus, a shallow surface zone of nearly uniform density and nearly uniform high temperature is formed. It is then characteristic that below this surface zone there is a zone where temperature decreases and density increases rapidly with depth, making the thermocline and the pycnocline or, if they occur together, the thermo-pycnocline. The rate of change of density with depth determines the water column's stability or unwillingness to move vertically. Turbulence may be unable to penetrate through this stable layer. Thus, exchange of materials between the layers above and below the thermo-pycnocline is markedly reduced. Materials that have densities just slightly greater than that of seawater tend to accumulate on the pycnocline or thermocline. The waters over many of the U.S. dredged material disposal sites will be too shallow to have either a pycnocline or thermocline

unless, of course, they are downcurrent of rivers where fresh water will over-ride the seawater. Those of intermediate depth, however, will display a shallow seasonal thermocline during the warm months. It will disappear in the fall when the winds increase and overturn the water column. Those disposal sites over 100 meters depth will very likely have a deep permanent thermocline, a summer thermocline, and a pycnocline.

Dissolved Oxygen

The atmosphere is the main source of oxygen dissolved in seawater and at the surface the water is usually very close to being saturated. In fact, at times (especially in spring) the water is supersaturated with oxygen that is a by-product of the photosynthesis carried on by the phytoplankton. Below the surface layers the water is seldom saturated because oxygen is consumed by living organisms and oxidation of detritus faster than it is transported from the air/sea interface. At depths between 500 and 1000 meters a layer of water occurs in which the oxygen content is less than it is either above or below. This, the oxygen minimum layer, is found only in the water column of the very deep dredged material disposal sites.

ZONATION OF THE CONTINENTAL SHELF

On the basis of their hydrography and biology, three shelf zones are generally recognized: the inner, middle, and outer continental shelf zones. The inner zone extends from shore out to a depth of 20 or 30 meters. As noted earlier, and as shall be seen in greater detail in Chapter II, something over 70% of the ocean dredged material disposal sites are located in this inner zone. This zone is generally very productive of marine plants from minute plankters to giant kelps. Most of the migratory finfish and invertebrates that spend parts of their lives in estuaries, such as croakers, spot, sand seatrout, and the white and pink shrimps, spend the remainder of their lives in the inner shelf zone. Local variations in salinity and temperature result in

play important roles in controlling the direction of currents on the shelf (Cherry 1969). Thus, the lower salinity adjacent to the mouth of a river results in a higher sea level there than farther out on the shelf; hence, the low density water flows seaward but as a result of the Coriolis effect turns to the right (when one is facing seaward in the northern hemisphere). Of importance to the fate of dumped dredged material in such places is the fact that as the surface water moves seaward because of density differentials, water must move shoreward along the bottom to replace it. This movement is generally sufficiently strong to transport some sediments landward.

The middle continental shelf zone, being farther from shore and deeper than the inner zone, is less influenced by river and estuarine waters. Also, far fewer estuarine-related species occur here. This zone extends to depths of 70 to 80 m and thus supports most of the dredged material disposal sites of intermediate depth (see Chapter II). It is in this middle shelf zone that the density current mentioned above flows the strongest. In many places this flow may be just the opposite of the wave-induced longshore current. This zone is a migration area for some fishes that move into deeper shelf waters in winter (where temperatures may well be higher than inshore) and then return to the inner shelf area or even estuaries in summer.

The outer continental shelf zone is only slightly affected by coastal phenomena. Salinities are higher, approximating those of the open ocean, and bottom temperatures are nearly uniform the year round. Hence, in winter they may be higher than those of shallow inshore waters that radiate heat to the colder atmosphere as fronts move across them. This outer shelf zone, which runs from 80 meters depth out to near the shelf break, is typically a relatively flat plain with some low relief features that vary regionally. For instance, off New England ridges and valleys characteristic of glacial moraine topography are observed; drowned reefs are seen off the southern and western coasts of Florida; diapiric hills (often salt domes) punctuate

the otherwise flat shelf of the northern Gulf; off the West Coast thrust fault blocks are not uncommon; and finally off the Hawaiian and Caribbean islands drowned coral reefs and some submarine volcanic features are observed. It is important to note also that the outer continental shelves of nearly all coasts are incised by the upper reaches of submarine canyons that continue down the continental slope. Off the West Coast of the U.S. the mainland shelf is so narrow that the heads of many canyons are close to shore where they trap and transport into deep water the sands that are being moved along southward in the inner shelf zone by wind-driven waves and their associated currents. Elsewhere the currents of the outer shelf are very much influenced by those of the open ocean over the slope. Many animals reside in the outer zone, including in the Gulf such shellfish as the brown shrimp.

One may document the multiresource nature of the continental shelves by noting that about 90% of the world's marine food resources, now caught and processed at the rate of about \$8 billion per year, comes from the shelves and adjacent bays (Holt 1969). At the same time about a fifth of the total world production of oil and gas, amounting to something over \$4 billion per year, comes from the shelf. Interestingly, the third shelf resource in terms of present dollar value (\$200 million per year) is sand and gravel.

THE CONTINENTAL SLOPE

OCEANOGRAPHY OF THE CONTINENTAL SLOPE

Even though only a few of the ocean dredged material disposal sites are situated on the continental slope, it is useful to compare its oceanographic characteristics with those of the shelf. The slope may be thought of as a transition area between the shallow, highly productive waters of the shelf, and the less productive waters of the deep oceans. However, as shall be noted later, the slope has its own

unique fauna.

The continental slope is the most significant topographic discontinuity of the earth's crust because it marks the general position of the contact between low-density rocks of the continents and the high-density rocks of the ocean floor (Emery and Uchupi 1972). The area of the slope is about twice that of the continental shelf, occupying 15.3 percent of the total area of the oceans, as compared with the 7.6 percent of the shelf. The slope has grades over 3 degrees and sometimes as high as 25 degrees. Most profiles across the continental slope show a steep, irregular upper slope and a smooth lower slope. Such are the cases for the northwestern Gulf of Mexico continental slope with its upper "hummocky zone" of diapiric structure origin and those of the Atlantic seaboard that possibly reflect a change from an erosional slope to a slumped and debris-covered slope. Directly off southern California and within the continental borderland the slope is a dip slope, whereas off Oregon and Washington, the slope is broken by normal faulting parallel to the shoreline.

In general the sediments of the continental slope are of a smaller grain size than those collected from the shelf but contain a higher percentage of organic matter than those on the shelf or on the deep-sea floor. Mass movements of these sediments may be common because the steepness of the slope is probably near the angle of repose of the sediment.

The slope zone is not only physically a transition between shelf and abyss, but also dynamically a transition zone. The upper slope receives some organic matter from the shelf and shares some species with the shelf; the middepth slope, with its own faunal assemblages, receives its organic matter from mesopelagic sources; and the lower slope, below 1000 m, is influenced by deeper currents and has yet another faunal assemblage. The fauna of the slope is characterized by its similarity in all the world ocean. It is to be expected that the

slope is less productive than the shelf, but it is by no means certain what the values are. So far as invertebrates are concerned, it is estimated that the biomass of the slope regions is only 10% of the shelf. However, it must be pointed out that most of the bottom-feeding fish, which are commercially important in shelf fisheries, also feed in the upper slope zones down to 700-800 m.

ZONATION OF THE UPPER CONTINENTAL SLOPE

The continental slope appears to support distinctive assemblages of bottom-dwelling organisms, some of which are of recognized commercial value or have that potential at and above depths of 1000 meters. In the Gulf of Mexico, Pequegnat et al. (1976) recognize the Shelf-Slope Transition Assemblage and three True Slope Assemblages between the shelf break and depths of 1050 m. Similar but not identical assemblages are found on the continental slopes of both the Atlantic and Pacific coasts.

According to the National Marine Fisheries Service in Pascagoula, Mississippi, the only commercial fisheries on the outer shelf and upper slope of the Gulf of Mexico are the red snapper and royal red shrimp. The most abundant demersal fish species here is the tilefish, but it is not fished commercially in appreciable amounts. Pelagic sport fish, such as marlin, occur over the shelf-slope intersection during the warm periods of the year.

The fishing industry of the northeastern U.S. is large and varied. Some 19 species of finfish and shellfish are fished on the upper continental slope. Principal among these are the lobster, cod, haddock, hake, flounder, ocean perch, scup, and pollock.

In the Mid-Atlantic Bight the catch is dominated by a list similar to the above with lesser importance of the cod and haddock.

In the South Atlantic Bight there is a pronounced paucity of demersal fishes which range to depths of the outer continental shelf and upper continental slope. It is true that both the royal red shrimp and red snapper live here, but the former is not yet fished in significant numbers.

On the Pacific Coast bottom fish caught by trawling represent an insignificant fraction of the total catch, which is dominated by pelagic fish such as tuna or inshore predatory fish such as halibut and rockfish. By contrast, in northern California and the northwest U.S., trawling and bottom longlining constitute a large portion of the fish landings. To the south the principal forms are sole, bocaccio, chilipepper, Pacific hake, and pandalid shrimp; to the north are black cod, ocean perch, pollock, Pacific hake, halibut, flounder, sole, pink shrimp, and Tanner crab.

II. GROUPING OF SITES BY PHYSICAL CHARACTERISTICS

INTRODUCTION

In order to design an effective and flexible oceanographic survey plan for either new or interim dredged material disposal sites, it is necessary to become familiar with the physical characteristics shared in common by the majority of U. S. dredged material disposal sites. Size, distance from shore, depth of water, and, to a lesser extent, shape of the existing DM sites are the most important considerations. These findings are summarized in this chapter.

Existing disposal sites have generally been located in areas where they will create minimal interference with heavy commercial or recreational navigation. Additionally, the sites were chosen to be as close as possible to those parts of channels requiring maintenance dredging. Many of the disposal sites have apparently been positioned in areas of past usage rather than beyond the continental shelf (as recommended, if possible) since only a small percentage (14%) reveal depths that exceed those limits of the continental shelf. Economics of transport could have been duly considered in view of the fact that only 6% of the sites are located outside of the 12-mile contiguous zone. Even then, the more distant ones are in proximity to a site of possible dredging requirement.

GENERAL CHARACTERISTICS

Those features considered in describing the dredged material disposal sites include depth, size, and distance from the nearest shoreline. Characteristics such as substrate composition and volume of material dumped per year have been taken into account; however, for the purpose

of this procedural guide, detailed and site-specific sediment analyses are not considered to be of utmost importance. Comprehensive studies such as Hathaway (1966) are available for some areas, but probably will serve a better purpose in implementation of the guide or in later impact assessment.

The important features have been compiled in Table 1 for present disposal sites used by various Corps Districts. Depth is shown in meters and has been divided into shallow (0-20 m), intermediate (21-99 m), and deep (>100 m) categories. The majority of disposal sites (70%) have shallow depths that range between 1 and 20 meters, whereas only 14% of the sites have depths in excess of 100 meters. Sizes of the disposal sites are nearly equally distributed between small (≤ 0.5 square nautical miles) and medium ($>0.5 - 3.9$ square nautical miles), 48% and 44%, respectively. Only 6% of the sites are situated outside of the 12-mile contiguous zone while 54% are found within the 3-mile territorial sea. Today the most common site is less than 20 meters deep, less than 4 square nautical miles ($n \text{ mi}^2$) in area, and within 12 n mi from the nearest shoreline. New sites will not necessarily follow this pattern in all details.

Other factors distinguishing the disposal sites include frequency of use, the amount of material received, and the sediment composition. Possible impacts of disposal operations from the continuous dredging necessary to permit medium draft vessels to enter Coos Bay will not be the same as those associated with a major project such as that proposed for Grays Harbor where a planned 16 million cubic yards of dredged material will be produced. Composition of the material varies tremendously; therefore, a comparison of the New York Mud Dump with Charleston's offshore site would reveal vast differences even though both sites receive similar quantities per annum. The dredged material from Charleston is largely clean silt and sand, whereas some materials removed from the New York Harbor complex are contaminated with sewage components (see Pequegnat et al. 1978). Sufficient data are not presently available for the construction of a table to show differences

Table 1
Characteristics of Ocean Dredged Material Disposal Sites

DISTRICT SITES	DEPTH*			SIZE**			DISTANCE***	
	Sh	Int	Dp	Sm	Med	Lg	Near	Int
ATLANTIC COAST (37)								
New England - 5	1	4		2	3		2	3
New York - 6	5	1		1	5		5	1
Philadelphia - 3	3			3			3	
Norfolk - 1	1			1			1	
Wilmington - 2	2			1	1		2	
Charleston - 4	4			3	1		4	
Savannah - 2	2			2			2	
Jacksonville - 14	11	1	2	6	8		8	6
CARIBBEAN (4)				4			3	1
GULF COAST (50)								
Jacksonville - 12	11	1		7	5		5	6
Mobile - 8	8			1	5	2	2	4
New Orleans - 19	19			6	10	3	13	5
Galveston - 11	11			5	2	4	6	3

(continued)

Table 1 (concluded)

DISTRICT SITES	Sh	DEPTH*		SIZE**			DISTANCE***		
		Int	Dp	Sm	Med	Lg	Near	Int	Dist
SOUTH PACIFIC (5)		5		5			5	2	1
PACIFIC COAST (31)									
Los Angeles - 5		1	4	5			5	2	5
San Francisco - 8	2	3	3	6	2		5		
Portland - 17	8	9		17			13	4	
Seattle - 1	1		1	1			1		
ALASKA (3)									
Total = 130	91	21	18	63	56	11	70	53	7
	(70%)	(16%)	(14%)	(48%)	(44%)	(8%)	(54%)	(41%)	(5%)

*Depth (meters)
 Sh = Shallow - 1-20
 Int = Intermediate - 21-99
 Dp = Deep - >100

**Size (square nautical miles)
 Sm = Small - 0.5
 Med = Medium - >0.5 - 3.9
 Lg = Large - >4.0

***Distance from Shore (nautical miles)
 Near = 0-3
 Int = Intermediate - >3-12
 Dist = Distant - >12

between the various disposal sites. Projected average annual dredging requirements as compiled by Dr. R.T. Saucier, Dredged Material Research Program, U.S. Army Engineer Waterways Experiment Station (WES) for individual Corps Districts (Pequegnat et al. 1978, Table 1) may be found in Chapter III of this report.

GROUPING OF SITES BY DEPTH

One of the most significant features of a disposal site, in relation to an oceanographic survey, is depth of water. This characteristic will be a factor in determining not only the length of time required per sampling station but also the size of ship and, more specifically, the type of equipment necessary to collect the samples. For example, the length of wire necessary to successfully trawl for benthic species is generally considered to be at least three times the water depth at the trawl station. Even though this scope requirement can be reduced slightly in deeper water, winch capacity for trawling in 1000 m water would have to be near 3000 meters, or similar to those winches found on oceanographic research vessels.

Depth of water will also govern the number of samples to be taken on the vertical axis at a sample station. That number will be quite small when working with a one-layered system but will increase with the two-layer and three-layer systems. More time, effort, and equipment will be required for a sufficient sampling program from a density-stratified system.

Depths of 20 meters or less are found at 91 of the 130 disposal sites (70% of the total), and eight of the subject Corps Districts are fortunate to have all of the disposal sites under their jurisdiction located in waters within this depth range (see Table 2). Another grouping of Districts with disposal sites similar in depth characteristics would include New York, Alaska, and Jacksonville Gulf. The majority of their disposal sites are within the shallow depth range but each of these Districts has one site in the intermediate depth range

Table 2
Depth Distribution of Ocean Disposal Sites
For Dredged Material By Corps District

CORPS OF ENGINEERS DISTRICT	DEPTH AT CENTER OF DISPOSAL SITE IN METERS (SPECIFIC DEPTH GIVEN IN PARENTHESIS)		
	1-20	21-99	>100
New Orleans	19		
Galveston	11		
Mobile	8		
Charleston	4		
Philadelphia	3		
Savannah	2		
Wilmington	2		
Norfolk	1		
Seattle	1		
Portland	8	9	
New York	5	1	
Alaska	2	1	
New England Division	1	4	
San Francisco	2	3	3 (183-238)
Jacksonville			
Gulf	11	1	
Atlantic	11	1	2 (156; 160)
Caribbean			4 (200-360)
Los Angeles		1	4 (168-457)
Hawaii			3 (501-1554)
Guam-Aprá			1 (1995)
American Samoa-Pago Pago			1 (2012)
Total = 130	91 (70%)	21 (16%)	18 (14%)

(21 - 99 m). Existing sites in the Portland District are nearly equally divided between shallow and intermediate depths whereas the New England Division has one shallow and four intermediate sites. San Francisco at present has almost equal distribution of sites in each of the depth categories, while sites under Jacksonville Atlantic (also in each category) tend to the shallow range. All of the remaining disposal sites, with the exception of one of the Los Angeles sites, are located in water depths exceeding 100 meters.

GROUPING OF SITES BY SIZE

The area encompassed by either an existing or a new disposal site will be used to determine the number of sampling stations required for production of sufficient data to characterize the oceanographic nature of the site and to provide bases for future monitoring and/or impact analysis. In order to arrive at the optimum number of stations per site, other variables (e.g., depth, season of the year, proximity to river outflow) must be considered in conjunction with size and configuration. Number and orientation of the collecting stations for both typical and atypical disposal sites will be discussed in Chapter V of this report.

Most dredged material sites are small (see Table 3). Almost half of the existing sites are less than 0.5 square nautical mile ($n\ mi^2$) in extent and only 11 sites (8%) cover $4.0\ n\ mi^2$ or more. In general, one will find that disposal sites on the West Coast are of the small category and that East Coast sites are generally medium in size ($>0.5 - 3.9\ n\ mi^2$). Gulf of Mexico sites vary through all of the size categories, probably due to the disproportionately large amount of dredged material produced in that region. The Charleston and Wilmington Districts are the only Districts outside of the Gulf that have what are considered to be large dredged material disposal sites ($>4.0\ n\ mi^2$). Very likely new dredged material disposal sites will be of moderate size, as stipulated in General Criterion No. 3 (Chapter I, p. 4).

Table 3
Size Distribution of Ocean Disposal Sites
For Dredged Material by Corps District

CORPS OF ENGINEERS DISTRICT	AREA OF DISPOSAL SITE (SQUARE NAUTICAL MILES)		
	≤ 0.5	$> 0.5 - 3.9$	≥ 4.0
Portland	17		
Los Angeles	5		
Philadelphia	3		
Alaska	3		
Seattle		1	
San Francisco	6	2	
Jacksonville			
Gulf	7	5	
Atlantic	6	8	
Caribbean		4	
New England Division	2	3	
New York	1	5	
New Orleans	6	10	3
Galveston	5	2	4
Mobile	1	5	2
Hawaii		3	
Guam-Apра		1	
American Samoa-Pago Pago		1	
Wilmington		1	1
Savannah		2	
Norfolk		1	
Charleston		3	1
Total = 130	62 (48%)	57 (44%)	11 (8%)

GROUPING OF SITES BY DISTANCE FROM SHORE

Distance from shore was determined as a straight line from the disposal site to the nearest shoreline and not to the nearest port or harbor. This factor discounts its usefulness in assessing transit time to and from the site and thereby negates any analysis as to the type of ship (e.g., day boat, overnight accommodations, etc.) required for survey of the disposal site. On the other hand, it was utilized with the ideas of oceanographic regimes, navigational aids, and the territorial sea in mind.

With respect to oceanographic regimes, several generalities can be listed for the proposed near category (<3 n mi). Longshore currents exert their influence within this nearshore zone while tidal currents and surge from wind and wave action add to turbulence and shoreline erosion. A higher degree of turbidity results from the net action of these physical forces than one finds farther offshore. Salinity within this zone is more variable due to coastal runoff and input of river systems; an overall tendency toward reduced salinity will be noted in the surface waters. Off the mouth of streams and rivers, this reduction is apparent even at near-bottom depths. In TerEco (1978), surface salinity in the Tiger Pass area was recorded as 0 ppt; off Bayou Fontanelle surface salinity was 7-8 ppt and near-bottom salinity was 15.5 ppt. These two waterways are distributaries of the Mississippi River within the bird-foot of the delta. Differences in salinity at the two sites can be attributed to the fact that Bayou Fontanelle is a locked passage whereas flow through Tiger Pass is not restricted.

Navigational publications refer to Loran systems and their accuracy, or even availability, for station positioning at the various disposal sites. For example, Loran C will not be available off California until December 1979. The territorial sea reaching to three miles offshore and the contiguous zone which extends to 12 miles were used

as breaks for the near, intermediate, and distant categories. Table 4 lists the number of disposal sites, by Corps District, in each of these distance-from-shore categories.

Ninety-five percent of the disposal sites are located within the 12-mile contiguous zone. San Francisco and those Districts with jurisdiction in the Gulf of Mexico control dumping at all of the sites seaward of the 12-mile limit. These five Corps Districts also have disposal sites in the near and intermediate categories. Alaska, Wilmington, and Philadelphia sites are all within the territorial sea whereas Norfolk, Charleston, Savannah, Hawaii, Los Angeles, and Seattle have all of the sites under their jurisdiction positioned within the intermediate category. The balance of the Corps Districts have sites in both the near and the intermediate zones.

DISTRIBUTION OF SITES AMONG PHYSICAL REGIMES AND BIOLOGICAL PROVINCES

Circulation regimes, constituted of water masses and currents, are fundamental determiners of both geomorphic regions and biological provinces, but circulation is in turn clearly affected by visible and submarine geomorphology. There are geometric constraints to circulation provided by the topography of the shoreline as well as by the continental margin (Mooers 1976). Two adjacent circulation systems are often separated by a prominent geologic feature (e.g., Cape Hatteras) with which they interact, and, moreover, the same statement can, in essence, be made in regard to biological provinces.

There is considerable regularity of occurrence of marine organisms within a biological province, whereas there should be apparent differences between a given province and the adjacent ones on each side of it. On occasion one finds that two distinctly separated but contiguous biological provinces can have very similar faunas. For example, the Louisianian of the northern Gulf of Mexico shares many

Table 4
Distance Distribution of Ocean Disposal Sites
For Dredged Material by Corps District

CORPS OF ENGINEERS DISTRICT	DISTANCE FROM SHORE (NAUTICAL MILES)		
	0-3	>3-12	>12
Philadelphia	3		
Alaska	3		
Wilmington	2		
Portland	13	4	
New York	5	1	
New England Division	2	3	
Jacksonville			
Atlantic	8	6	
Caribbean	3	1	
Gulf	5	6	1
New Orleans	13	5	1
Galveston	6	3	2
Mobile	2	4	2
San Francisco	5	2	1
Los Angeles		5	
Charleston		4	
Hawaii		3	
Guam-Aprá	1		
American Samoa-Pago Pago	1		
Savannah		2	
Norfolk		1	
Seattle		1	
Total = 130	70	53	7
	(54%)	(41%)	(5%)

species with the Carolinian of the South Atlantic Bight. This is the result of the long submergence in the past of what is now peninsular Florida, permitting climatic continuity between the geographic areas without the present tropical separation.

In spite of all the apparent complexities and possible differences, there are regular and unifying factors operating within the geomorphic-oceanographic-biologic regimes that bring forth more common factors than differences. Pequegnat et al. (1978) have tabulated these three diverse entities for the continental United States and its territories into a single, productive display which indicates various fundamental relationships. These authors infer that no matter how different ocean waters may appear to be from one region to another, the important factors governing the behavior of disposed dredged material will not differ in kind but only in degree from place to place.

Pequegnat et al. (1978) have drafted maps to show the relationship of geomorphic regions and biological provinces to one another and to the various Corps Districts. They appear as Figures 7, 8, and 9. Table 5 shows the relationship between Corps Districts and biological provinces.

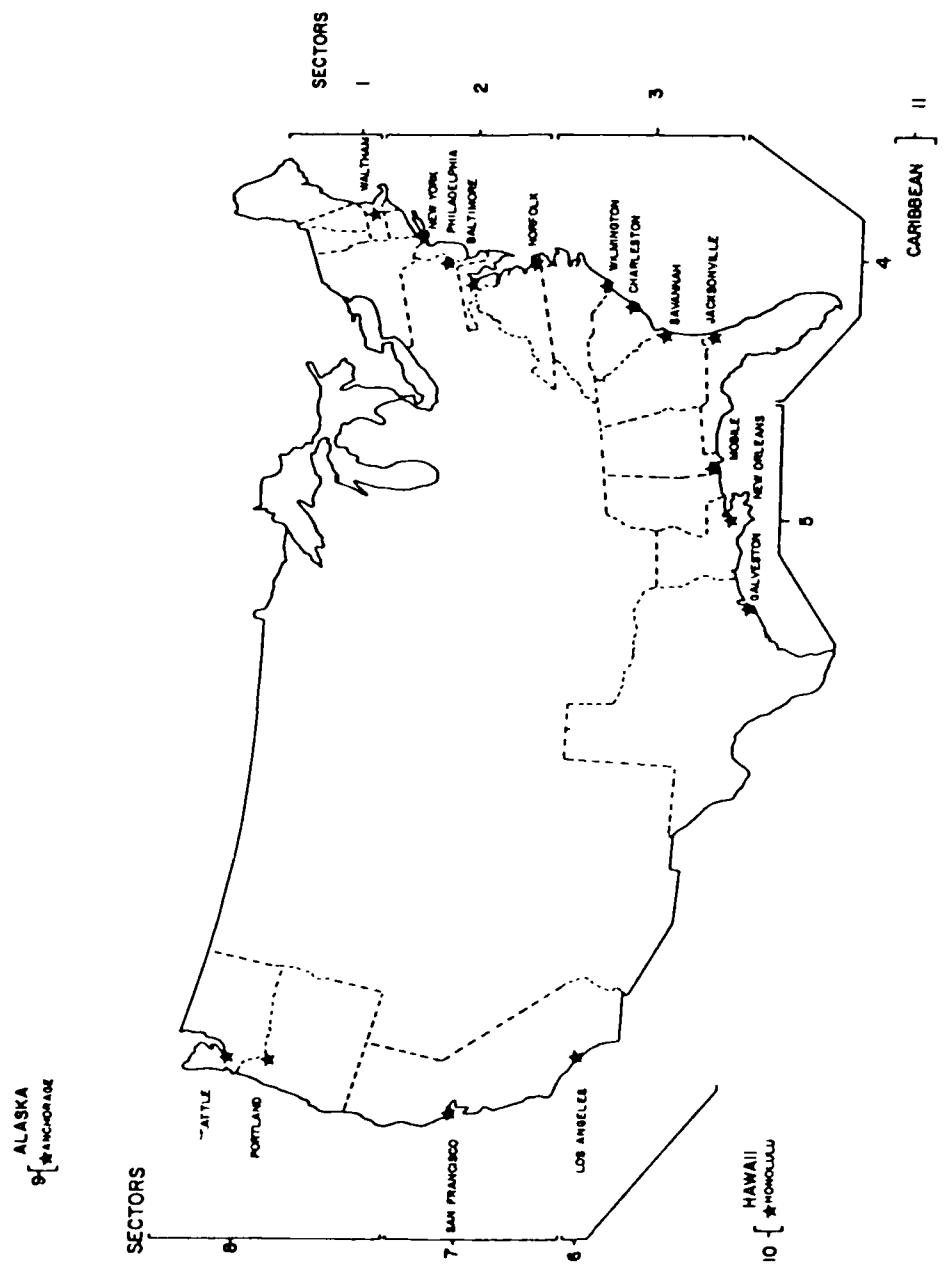


Figure 7. Sectors of the United States in relation to the Corps Districts

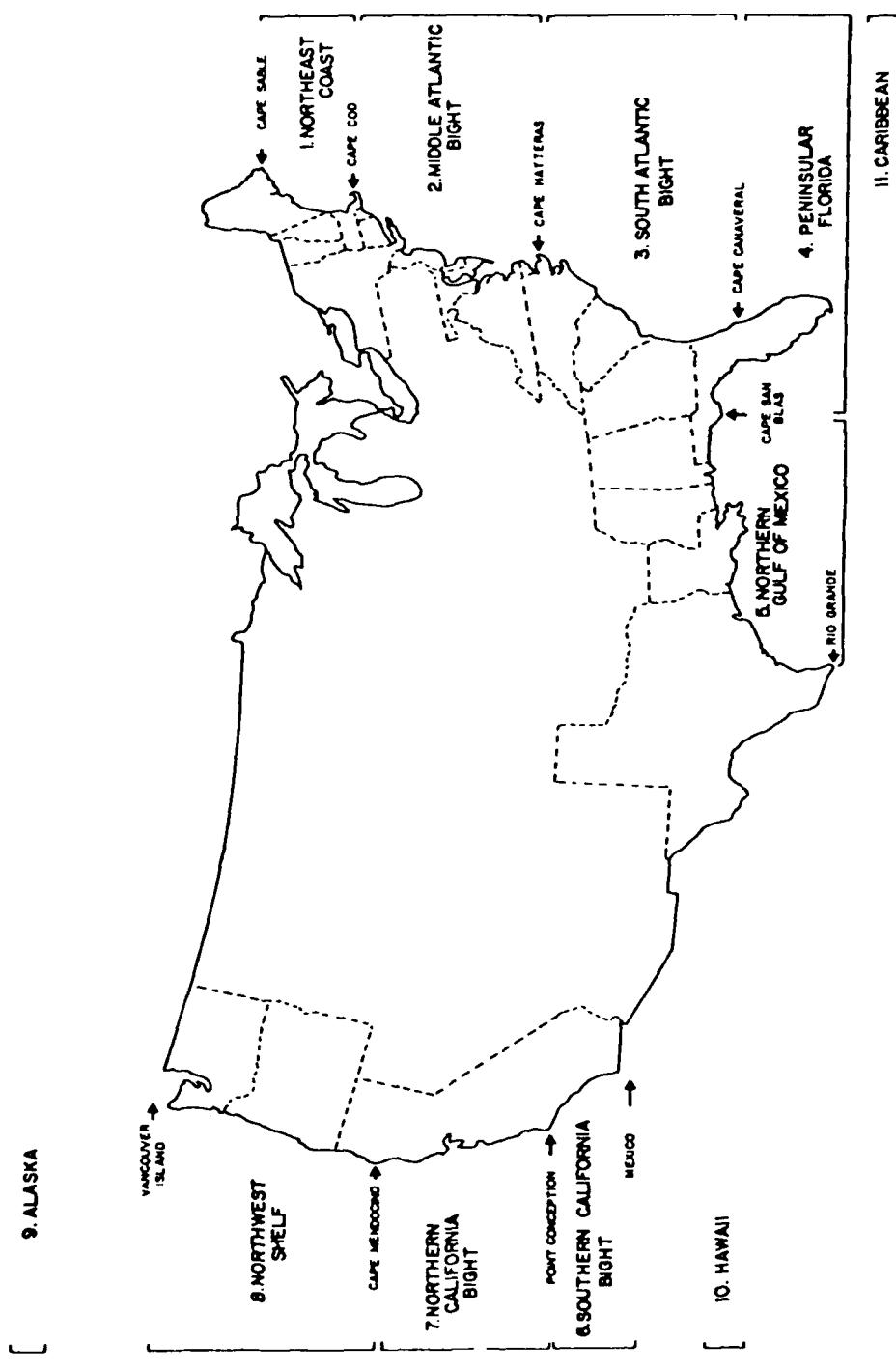


Figure 8. Sectors of the United States showing the related geomorphic regions

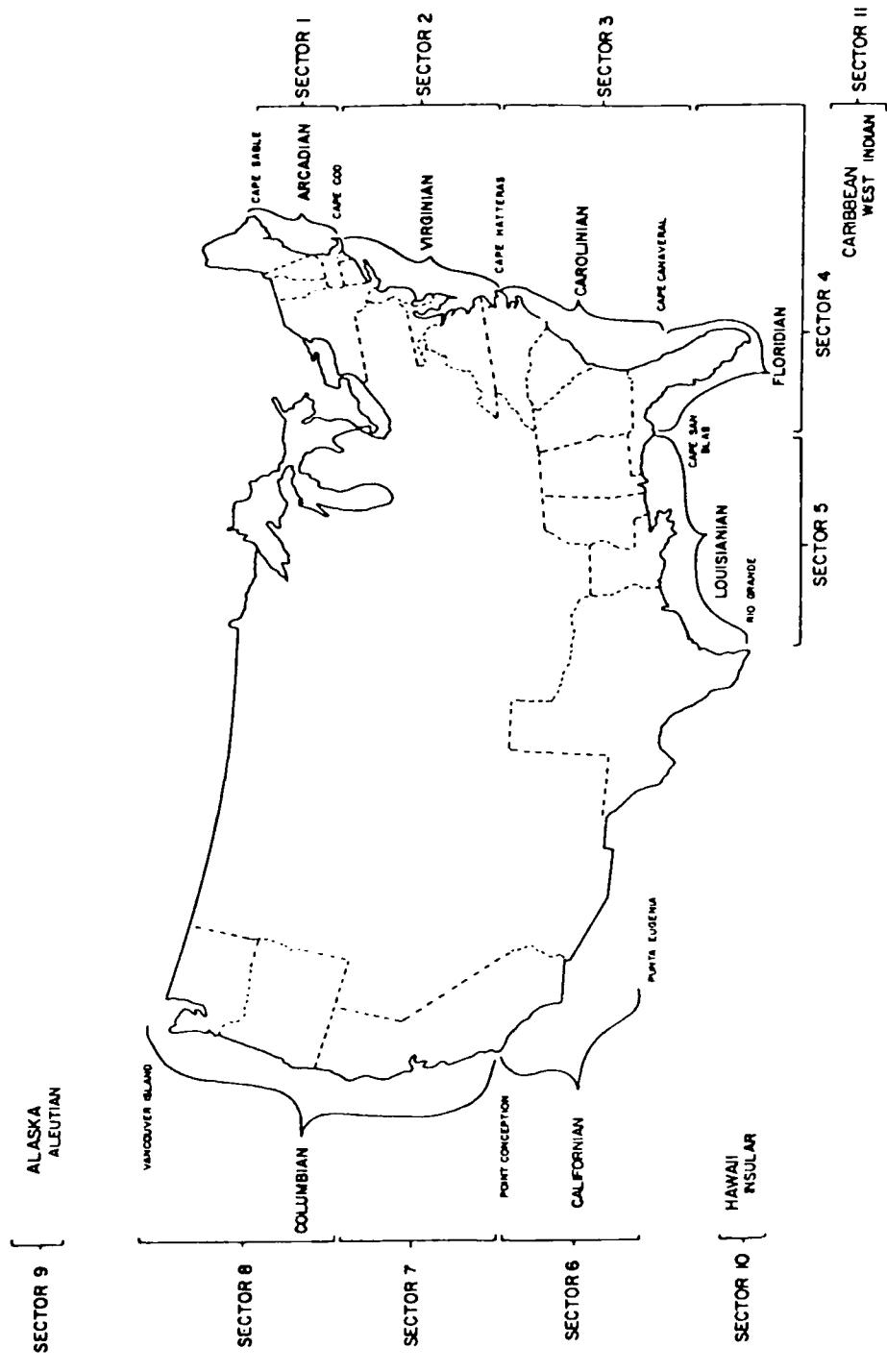


Figure 9. Sectors of the United States in relation to biological provinces

Table 5
Assignment of Corps Districts to Biological Provinces

ARCADIAN

New England Division

VIRGINIAN

New York District
Philadelphia District
Norfolk District

CAROLINIAN

Wilmington District
Charleston District
Savannah District
Jacksonville District - Atlantic sites above 28°30'N

FLORIDIAN

Jacksonville District - Atlantic sites below 28°31'N
Jacksonville District - Gulf sites

WEST INDIAN

Jacksonville District - Caribbean sites

LOUISIANIAN

Mobile District
New Orleans District
Galveston District

INSULAR

Hawaii District

CALIFORNIAN

Los Angeles District

COLUMBIAN

San Francisco District
Portland District
Seattle District

ALEUTIAN

Alaska District

III. ANALYSIS OF SITES BY DISTRICTS

The distribution among Districts of the present 130 interim sites, as well as their general characteristics, are discussed in this chapter. This information provided guidance in shaping the recommended survey plan presented in Chapter V. Workshop discussions indicated that the data will be useful to the District Engineer who wants to compare his maintenance problems and costs, as well as survey and monitoring costs, with those of other Districts. This information will also provide guidance to the Corps in the selection of new sites and to EPA in evaluating the acceptability of new sites presented for designation.

The 130 proposed interim disposal sites are randomly distributed among 17 Districts when the New England Division is included as one of those Districts. Since the Jacksonville District has been separated into Jacksonville Atlantic, Caribbean, and Jacksonville Gulf for the purpose of this report, there will be analyses of sites for 19 Districts that have been grouped according to geographical location. These groups include Atlantic Coast, Caribbean, Gulf Coast, Pacific Ocean, Pacific Coast, and Alaska.

ATLANTIC COAST

Those eight Corps Districts situated along the eastern seaboard have jurisdiction over 41 of the proposed disposal sites. These sites have physical characteristics with average values of 24 meters depth at the center of the site (the position used for all depths shown in this section) and 1.35 square nautical miles area. During the years of 1974 and 1975, ocean disposal of dredged material in the Atlantic amounted to $14.5 \times 10^6 \text{ m}^3$ and $18.7 \times 10^6 \text{ m}^3$, respectively (U.S. EPA 1976a).

NEW ENGLAND DIVISION

None of the sites within this Division are deeper than 100 meters,
52

larger than 4 square nautical miles, or more than 12 nautical miles distance from shore. The New England Division sites are given in Table 6 for the individual disposal sites. Survey sampling programs of Types A and E (described in Chapter V) will be required for the new England disposal sites.

Table 6
Characteristics of New England Disposal Sites

<u>SITE</u>	<u>DEPTH</u> m	<u>AREA</u> n mi ²	<u>DISTANCE</u> n mi	<u>SURVEY</u> TYPE
Portland	34	0.8	4.5	A
Newburyport	20	0.25	1.0	A
Cape Arundel	30	0.05	2.8	E
Marblehead	93	3.14	11.0	E
Boston	24	0.8	4.2	E

Site-specific sediment data concerning the substrate below these five disposal sites are not available; however, Pequegnat et al. (1978) report the general surficial sediment on the continental shelf of this region to be primarily well-sorted sands composed largely of quartz and feldspar with some glauconite, heavy minerals, and rock fragments. Several large deposits of gravel or sandy gravel also occur (Schlee 1973) scattered throughout the Gulf of Maine with clays and silts predominating on the continental slope (Trumbull 1972).

Saucier projected that dredging requirements of the Corps of Engineers in the New England Division would average 1.8×10^6 m³ annually from 1974-1976; 0.9×10^6 m³ of that volume would be in the form of maintenance dredging (Pequegnat et al. 1978, Table 1). These quantities are small in comparison to amounts dredged by other Corps Districts along the Atlantic coast.

NEW YORK DISTRICT

The six disposal sites under New York District are shallow to inter-

mediate in depth (<100 m), close to shore (<12 n mi distance), and small to medium in size (<4 n mi²). The individual sites are listed in Table 7. Types A, B, and E of the survey sampling program outlined in Chapter V are those which should be used by the New York District for the designated disposal sites.

Table 7
Characteristics of New York Disposal Sites

<u>SITE</u>	<u>DEPTH</u> <u>m</u>	<u>AREA</u> <u>n mi²</u>	<u>DISTANCE</u> <u>n mi</u>	<u>SURVEY</u>
				<u>TYPE</u>
Fire Island	7	1.1	0.3	B
Jones Inlet	9	1.2	0.4	B
East Rockaway	8	0.8	0.6	B
Rockaway Inlet	10	0.4	1.0	A
Mud Dump	27	2.2	5.8	E
Shark River	13	0.6	0.5	E

Charnell (1975) shows the surface sediment of the New York Bight to be predominantly sand sized with mud occurring in the low areas, namely in the axis of the Hudson Shelf Valley and in the Christiaensen Basin. Only the Mud Dump is positioned in proximity to the latter basin; the other disposal sites are within one nautical mile of the shoreline on the innermost aspects of the continental shelf where sands should tend to predominate. During their monitoring activities in July 1978, TerEco Corporation obtained several box cores within and around the perimeter of the Mud Dump. Without exception, those cores showed the basic surficial sediment to be sand, ranging in size from fine to coarse. A black silty ooze was noted in a few of the samples but the amounts were always small, thereby giving it a secondary ranking to the generally well-compacted sands obtained in the cores.

The New York District, one of the larger dumpers of dredged material along the East Coast, was projected to dispose of 9.6×10^6 m³ annually

from 1974 to 1976 (Pequegnat et al. 1978). Of that volume, 4.2×10^6 m³ would be in the form of maintenance material while the balance would constitute new work. The Mud Dump receives about 5.9×10^6 m³ of the dredged material annually, much of it from commercial dredgers in New York Harbor.

PHILADELPHIA DISTRICT

The three dredged material disposal sites for the Philadelphia District are very small in size when compared to those of other Corps Districts along the Atlantic seaboard. All of the sites are shallow in depth and proximal to shore (see Table 8 below); therefore, survey sampling of Type B should provide adequate coverage.

Table 8
Characteristics of Philadelphia Disposal Sites

SITE	DEPTH m	AREA n mi ²	DISTANCE n mi	SURVEY TYPE
Manasquan Inlet	7	0.03	0.3	B
Absecon Inlet	6	0.04	0.8	B
Cold Spring Inlet	6	0.04	0.7	B

In this region of the Mid-Atlantic Bight, almost the entire shelf is covered by subarkosic sand ranging in size from medium to very fine and rarely containing more than a small percentage of silt or clay (Milliman et al. 1972). Gravel or sandy gravel deposits are located in various areas on the shelf with the largest lying south of the Hudson Shelf Valley (Schlee 1973). One might speculate that surficial sediments underlying the disposal sites could contain a slightly greater percentage of finer sediment since the sites are so near the shoreline. Holocene reworking is thought to have removed fine-grained sediment from a majority of the shelf and probably transported it landward with currents and waves. TerEco personnel noted during field

studies that the nearshore water along that stretch of coastline extending from Cape May to Atlantic City, New Jersey, was continuously turbid during late July and early August of 1977. Such would indicate the presence of finer grained sediment being reworked and suspended in the water column.

Dredging requirements for the Corps of Engineers Philadelphia District have been estimated to average $9.6 \times 10^6 \text{ m}^3$ ($7.2 \times 10^6 \text{ m}^3$ in the form of maintenance dredging) during the years of 1974 to 1976 (Pequegnat et al. 1978). Such a volume would rank fourth among the eight Districts of the Atlantic coast.

NORFOLK DISTRICT

The Norfolk District, with its single dredged material disposal site, is one of the smaller dumpers of those Corps Districts along the Atlantic seaboard. The site is in shallow water, of intermediate size, and within the 12-mile contiguous zone (see Table 9 for actual measurements). The site would require a survey sampling program of Type B as described in Chapter V of this report.

Table 9
Characteristics of Norfolk Disposal Site

SITE	DEPTH m	AREA n mi ²	DISTANCE n mi	SURVEY TYPE
Dam Neck	12	3.0	3.3	B

Most of the Hatteras - Cape Cod shelf is mantled by fine to medium quartz and feldspar sands that are, in places, interbedded with silt and clay layers. Milliman et al. (1972) feel that a significant portion of modern nearshore sediment may have been derived through landward movement of fine-grained sediment from the central and outer shelf. In the shallower aspects, features of small magnitude are

believed to change their shape or their cover of sand ripples with each tide or tidal cycle.

The Corps estimates that the annual average of dredging requirements for the Corps of Engineers, Norfolk District, was about $3.4 \times 10^6 \text{ m}^3$ between 1974 and 1976. Maintenance dredging would account for $3.3 \times 10^6 \text{ m}^3$ with the balance being in the form of new work. These data were obtained from Table 1 in Pequegnat et al. (1978).

WILMINGTON DISTRICT

Although this District has only two disposal sites, the volume of material to be dumped annually ranks second among the Atlantic coast Corps Districts. The two disposal sites are medium to large in size and positioned over shallow water; such criteria would require Type B and C sampling survey programs (see Chapter V). Table 10 gives the physical characteristics of these sites.

Table 10
Characteristics of Wilmington Disposal Sites

SITE	DEPTH m	AREA n mi ²	DISTANCE n mi	SURVEY TYPE
Morehead City				
Harbor	13	2.6	1.6	B
Wilmington Harbor	13	23.2	0.9	C

Surficial sediments on the inner shelf between Cape Lookout and Cape Fear are predominantly sand with a few isolated calcareous banks and a large patch of gravelly sand that runs east-southeast of Smith Island (Corsline 1963, Hollister 1973, U.S. Dept. of Interior, Bureau of Land Management (BLM) 1977). The sands contain varying amounts of shell debris to which there have been many types of organic contributors. Both of the Wilmington disposal sites are positioned over areas of

sandy bottom and clear of the scattered hard banks.

The Wilmington District Corps of Engineers has been shown to have annual dredging requirements that will average about $10.1 \times 10^6 \text{ m}^3$ for 1974-1976 (Pequegnat et al. 1978). Of that total volume, $6.8 \times 10^6 \text{ m}^3$ will be in the form of maintenance dredging with the balance being new work. In 1978, however, it disposed of only $1.5 \times 10^6 \text{ m}^3$ (personal communication, Barry W. Holliday, Wilmington District, July 1979).

CHARLESTON DISTRICT

The four dredged material disposal sites within limits of the Charleston Corps District are all positioned within the 12-mile contiguous zone. Three of these sites are of intermediate size and one is in the large category (see Table 11). Sampling survey plans of Types A, B, and C will be necessitated by the various physical characteristics of these disposal sites.

Table 11
Characteristics of Charleston Disposal Sites

SITE	DEPTH m	AREA n mi ²	DISTANCE n mi	SURVEY TYPE
Georgetown Harbor	9	1.1	3.5	B
Charleston Harbor	11	11.8	6.7	C
Port Royal Harbor #1	6	0.8	4.9	A
Port Royal Harbor #2	13	1.0	7.7	B

Surficial sediments on the floor of the Atlantic off South Carolina are almost entirely sandy in relation to grain size and well sorted with respect to texture (Hollister 1973). In general, the sands are unimodal, with the exception of a small area off Charleston Harbor where silt represents 20 - 40% of the surface sediment. Gossline

(1963) reports that along the nearshore portions of the South Carolina marsh coast one will find detritals being transported and deposited.

The Corps indicates the projected average annual Corps of Engineers dredging requirements for the Charleston District to be $8.0 \times 10^6 \text{ m}^3$ ($6.8 \times 10^6 \text{ m}^3$ in maintenance dredging) in Table 1 of Pequegnat et al. (1978). A slightly higher amount, $10.3 \times 10^6 \text{ m}^3$, has been reported by U.S. Dept. of Interior, BLM (1977) in their draft environmental impact statement for the South Atlantic oil and gas lease sale.

SAVANNAH DISTRICT

Both disposal sites within this District are all of medium size and have been positioned in shallow water; these criteria indicate a need for the Type B sampling survey plan outlined in Chapter V. The disposal sites are within 7 nautical miles of the shore and in proximity to areas of dredging. Table 12 gives more specific data relative to these sites.

Table 12
Characteristics of Savannah Disposal Sites

SITE	DEPTH m	AREA n mi ²	DISTANCE n mi	SURVEY TYPE
Savannah River	12	3.9	4.5	B
Brunswick Harbor	11	2.1	6.6	B

Sand-sized material predominates in the submarine surface sediment of the inner continental shelf off the coast of Georgia. Hollister (1973) shows two small, nearshore areas where silt constitutes 20 - 40% of the sediment. These areas are just to the south of Altamaha Sound and St. Andrews Sound, respectively. In addition, a patch containing 10 - 30% gravel appears just offshore at the 32nd parallel.

U.S. Dept. of Interior, BLM (1977) shows slightly higher values for the volume of dredged material to be disposed ($9.3 \times 10^6 \text{ m}^3$) annually than does Pequegnat et al. (1978) ($6.9 \times 10^6 \text{ m}^3$). Maintenance dredging accounts for almost all of the material dredged within the Savannah Corps District with continuous dredging of the inner Savannah Harbor the major source of supply.

JACKSONVILLE DISTRICT (ATLANTIC)

Fourteen dredged material disposal sites along Atlantic peninsular Florida are assigned to the Jacksonville District. The majority of the disposal sites (11) are in shallow water; all are less than four square nautical miles in size, and all are within the 12-mile contiguous zones (see Table 13). Sampling survey plans of Types A, B, E, and H will be required for these interim designated dredged material disposal sites.

Table 13
Characteristics of Jacksonville Atlantic Disposal Sites

SITE	DEPTH m	AREA n mi ²	DISTANCE n mi	SURVEY TYPE
Fernandina Harbor	12	1.0	6.2	B
Jacksonville Harbor	14	1.0	5.0	B
St. Augustine Harbor #1	4	0.6	0.6	B
St. Augustine Harbor #2	7	0.4	0.7	A
Ponce de Leon Inlet #1	8	0.2	0.5	A
Ponce de Leon Inlet #2	6	0.1	0.7	A
Canaveral Harbor	14	2.7	4.8	B
Ft. Pierce Harbor	15	1.0	4.6	B
St. Lucie Inlet	2	0.1	0.5	A
Palm Beach Harbor #1	2	0.1	0.2	A
Palm Beach Harbor #2	156	1.0	3.4	H
Port Everglades Harbor	98	0.9	2.1	E
Miami Beach	160	1.0	4.3	H
Largo Sound	2	0.1	0.2	A

Hollister (1973) depicts surface sediment on the continental shelf east of Florida to be predominantly sand in consistency except for the

nearshore region between Saint Augustine and Cape Canaveral which is classed as a silty sand. Such occurrences tend to confirm Uchupi's (1963) finding that from shore to a depth of 24-29 m, the shelf from Cape Hatteras to Cape Canaveral is marked by fine sand, silty sand, and sandy silt. Patches of gravelly sand are located to the south of both Melbourne and Miami at distances a bit farther from shore. Hard banks and reefs are sparsely scattered along almost the entire east coast of Florida (U.S. Dept. of Interior, BLM 1977).

The Jacksonville Corps District disposes of more dredged material than any other District along the Atlantic coast (Table 1 in Pequegnat et al. 1978); however, since U.S. territories in the Caribbean are not included in that table, it is possible that their volume of dredged material is included in that of Jacksonville ($11.7 \times 10^6 \text{ m}^3$). Maintenance dredging accounts for approximately $2.7 \times 10^6 \text{ m}^3$ of the above total volume. The rest was new work from 1974-1976.

CARIBBEAN

United States territorial holdings in the Caribbean fall under the jurisdiction of the Jacksonville Corps of Engineers District and Region II EPA. Four dredged material disposal sites off Puerto Rico have been designated as interim disposal sites. All are in water greater than 100 meters deep, and each is in the medium size range ($>0.5 - 3.9 \text{ n miles}^2$); Type H of the sampling survey plan is suggested for these disposal sites. All of the proposed sites are within the 12-mile contiguous zone and three of them are within the 3-mile territorial sea (see Table 14).

Puerto Rico rises from a relatively shallow submerged bank which falls away into the sea in an irregular pattern. Its insular shelf is extremely narrow along the north shore (2 - 3 km) and less than 10 km wide along the southern coast. Individual coral heads and banks are scattered over the shelf from very near shore to the seaward end

the shelf. The U.S. Naval Oceanographic Office (1972) shows that bottom sediments are dominantly fine grained (i.e., calcareous sandy mud) in the deep water area around Puerto Rico. One core, taken from the slope to the north, was classed as a silty clay while another core from the south side of the island was considered to be a sandy mud. On the shelf proper, calcareous sands are found in varying thicknesses that range from about 3 inches upward to several feet in places where surface irregularities augment accumulation.

Table 14
Characteristics of Caribbean Disposal Sites

<u>SITE</u>	<u>DEPTH m</u>	<u>AREA n mi²</u>	<u>DISTANCE n mi</u>	<u>SURVEY TYPE</u>
San Juan Harbor	263	1.0	2.2	H
Arecibo Harbor	284	1.0	1.8	H
Mayaguez Harbor	200	1.0	2.8	H
Ponce Harbor	360	1.0	3.8	H

GULF COAST

The Gulf of Mexico is served by four Corps Districts that have jurisdiction over 50 of the proposed interim dredged material disposal sites. These Gulf disposal sites are characterized by average values of 9 meters water depth and an area of approximately 1.58 square nautical miles. U.S. EPA (1976a) reports that during calendar years 1974 and 1975, the Corps of Engineers utilized ocean disposal of dredged material to the extent of $49.9 \times 10^6 \text{ m}^3$ and $33.5 \times 10^6 \text{ m}^3$, respectively.

JACKSONVILLE DISTRICT (GULF)

The Jacksonville District has twelve disposal sites in the Gulf. A majority of the sites (92%) are positioned in shallow water and they are about equally divided between small and medium in size. Three

types of survey sampling plans will be required for the Jacksonville District to have sufficient coverage to ascertain possible impacts due to dredged material disposal; these include Types A, B, and E as described in Chapter V of this report. Specific physical characteristics concerning these disposal sites may be found in Table 15.

Table 15
Characteristics of Jacksonville Gulf Disposal Sites

<u>SITE</u>	<u>DEPTH</u> <u>m</u>	<u>AREA</u> <u>n mi²</u>	<u>DISTANCE</u> <u>n mi</u>	<u>SURVEY</u> <u>TYPE</u>
Key West	64	1.1	6.2	E
Charlotte Harbor	12	1.0	7.2	B
Tampa Harbor #1	15	0.6	14.0	B
Tampa Harbor #2	13	1.0	10.2	B
Anclove	2	0.4	3.3	A
Pithlachascotee River	1	0.6	1.0	A
Withlacoochee River #1	2	0.2	2.2	A
Withlacoochee River #2	2	0.2	0.8	A
Cedar Keys #1	3	0.12	3.8	A
Cedar Keys #2	4	0.13	3.9	A
Horseshoe Cove #1	1	0.03	1.0	A
Horseshoe Cove #2	1	0.03	0.4	A

Unconsolidated sediments over the west Florida shelf include recent and relict carbonate sediments that are thin and discontinuous (Brooks 1974). The vast majority of this sediment veneer is biogeneous (i.e., coral debris, mollusk shells, foraminifera tests) in origin and represent various stages of decomposition or disintegration. Scattered low outcrops of limestone and chert provide a substratum for coral and sponge growth.

Jacksonville District dumps the smallest amount of dredged material of those Corps Districts in the Gulf region. The average annual dredging requirement of Jacksonville is approximately $9.8 \times 10^6 \text{ m}^3$ ($2.7 \times 10^6 \text{ m}^3$ in the form of maintenance work) for 1974, 1975, and 1976 (Pequegnat et al. 1978).

MOBILE DISTRICT

The Mobile Corps District has jurisdiction over eight of the Gulf dredged material disposal sites. All of them are in shallow water (<20 m) but they range in size from small through large and are positioned at varying distances from the coastline. Types A, B, and C of the survey sampling plans described in Chapter V should be applied by the Mobile District to the disposal sites; proper assignment of survey type to disposal site is shown in Table 16.

Table 16
Characteristics of Mobile Disposal Sites

<u>SITE</u>	<u>DEPTH</u> m	<u>AREA</u> n mi ²	<u>DISTANCE</u> n mi	<u>SURVEY</u> <u>TYPE</u>
Port St. Joe #1	12	1.2	7.4	B
Port St. Joe #2	13	1.0	7.4	B
Panama City	16	0.2	1.2	A
Pensacola	11	0.7	2.6	B
Mobile	14	4.8	5.2	C
Pascagoula	11	1.2	8.3	B
Gulfport #1	8	4.0	13.8	C
Gulfport #2	8	2.3	14.7	B

Sediments between the Mississippi Delta and western Florida have been described by Upshaw et al. (1966). Their work reveals that Mississippi Sound sediments are composed mostly of silt and clay with some areas of fine to medium sand. Medium and coarse sands dominate the mainland beaches west of the Pascagoula River and along the lee side of the barrier islands. Those areas seaward of the islands are mostly fine sands except for a notable, elongate mud area just off Dauphine Island. Fine sands, silts, and clays border the mainland east of Pascagoula and dominate the sediments of Mobile Bay. In general, one can conclude that particle size diminishes from the predominantly sandy bottom off Florida (Rinkel and Jones 1973) westward to the fine silts and clays of Mississippi. Except for local interruptions, coarse and medium

sands on the open shelf east of Mobile Bay grade into fine and very fine sands which in turn give way to silt and clay muds; the same trend also continues from north to south across the continental shelf. Sediments with a high percentage of sand encompass the Chandeleur Islands with fine sediments occupying the interior of the arc formed by the Chandeleurs (Coleman and Gagliano 1964).

The Mobile Corps District is shown by Saucier to have a projected average annual dredging requirement of $27.2 \times 10^6 \text{ m}^3$ for the years 1974 to 1976 (Pequegnat et al. 1978). Of that total, $19.3 \times 10^6 \text{ m}^3$ would be in the form of maintenance dredging with the balance being new work.

NEW ORLEANS DISTRICT

Major rivers such as the Mississippi and the Atchafalaya empty into the Gulf in the New Orleans Corps District where the largest volume of dredged material in the United States and its territories is disposed. Nineteen separate disposal sites fall within New Orleans' jurisdiction. All of the sites are located in shallow water, but are variable in respect to size and distance from the nearest shore. Nonetheless, all of these disposal sites can be satisfied by utilization of only three of the sampling survey plans outlined in Chapter V. Table 17 designates the survey plan most suitable for each of the disposal sites and gives pertinent physical characteristics for the individual sites.

Surface sediments on the inner continental shelf of Louisiana from the Mississippi River to Sabine Pass and out to a depth of about 30 meters are highly variable in both physical and chemical characteristics (Tieh et al. 1973). Sedimentary facies in the silt-clay mode that contain varying amounts of sand tend to predominate the nearshore area except for a stretch extending from Bastian Bay to a point just west of

Table 17
Characteristics of New Orleans Disposal Sites

<u>SITE</u>	<u>DEPTH m</u>	<u>AREA n mi²</u>	<u>DISTANCE n mi</u>	<u>SURVEY TYPE</u>
Mississippi River Gulf Outlet	6	4.0	9.0	C
Mississippi River South Pass	17	0.4	1.7	A
Mississippi River Southwest Pass	6	3.2	2.7	B
Mississippi River Tiger Pass	2	1.1	1.2	B
Empire-Bayou Fontanelle Waterway	3	0.1	0.4	A
Barataria Bay Waterway	3	0.9	1.9	B
Bayou Lafourche Waterway	3	0.3	0.8	A
Houma Navigation Channel	4	2.2	10.0	B
Atchafalaya River	4	6.5	7.0	C
Mermentau River #A	4	0.2	0.9	A
Mermentau River #B	5	0.3	1.2	A
Freshwater Bayou	4	0.7	1.9	B
Calcasieu River & Pass #A	2	0.5	0.6	A
Calcasieu River & Pass #B	4	0.8	0.7	B
Calcasieu River & Pass #C	6	3.9	3.4	B
Calcasieu River & Pass #D	11	4.1	10.4	A
Calcasieu River & Pass #E	12	2.9	15.2	B
Calcasieu River & Pass #F	5	1.5	2.2	A
Calcasieu River & Pass #G	3	0.3	0.9	A

Isle Dernieres. In that area the sediments are characterized by modes in the fine to very fine sand classes; similar surficial sediments are found offshore of Atchafalaya and Vermilion Bays. Coarser sands in the form of relict sediments are reported offshore in the western part of the area in the vicinity of Calcasieu Pass.

Saucier estimates that the New Orleans Corps District would have average annual dredging requirements of approximately $111.3 \times 10^6 \text{ m}^3$ ($64.6 \times 10^6 \text{ m}^3$ in the form of maintenance work) for the three-year period of 1974-1976 (Pequegnat et al. 1978). New work would account for the difference in those volumes.

GALVESTON DISTRICT

The Galveston District ranks second among all Corps Districts in the amount of dredged material to be dumped each year. Eleven of the disposal sites are within the limits of this District and all are situated in shallow water. They vary in size from small to large and range in proximity to shore from 0.5 nautical mile to a distance of more than 15 nautical miles. Table 18 shows types of the sampling survey plans which are best suited for each of the individual disposal sites.

Recent sediments on the continental shelf of the northwest Gulf of Mexico are divisible primarily into nearshore sands and shelf facies muds (silty clays and clayey silts). Extensive areas are covered by alternating sands and muds (see Curray 1960). The basal sands are exposed at the surface near the shoreline and across most of the shelf off the Rio Grande and much of east Texas and western Louisiana (although here there tends to be more alternation of sands and muds). The shelf facies overlies the basal facies off central Texas, particularly in a band running from Freeport to Aransas (TerEco 1972).

Table 18
Characteristics of Galveston Disposal Sites

<u>SITE</u>	<u>DEPTH</u> m	<u>AREA</u> n mi ²	<u>DISTANCE</u> n mi	<u>SURVEY</u> TYPE
Sabine-Neches Waterway #1	11	2.4	15.9	B
Sabine-Neches Waterway #2	11	4.8	12.8	C
Sabine-Neches Waterway #3	12	4.7	8.0	C
Sabine-Neches Waterway #4	7	4.2	4.2	C
Galveston Harbor	12	6.4	5.4	C
Freeport Harbor	9	0.4	1.7	A
Matagorda Channel	8	0.4	2.1	A
Corpus Christi Channel	11	0.4	2.2	A
Port Mansfield #1	8	0.1	0.9	A
Port Mansfield #1A	7	0.1	0.5	A
Brazos Island Harbor	14	0.6	1.7	B

The Galveston Corps of Engineers District had a projected average annual dredging requirement of 53.8×10^6 m³ for the calendar years 1974, 1975, and 1976 (see Table 1 in Pequegnat et al. 1978). Maintenance dredging will probably account for 40.9×10^6 m³ of that volume; the balance will be new work.

PACIFIC OCEAN

United States territorial holdings in the Pacific Ocean fall under the jurisdiction of the Honolulu, Hawaii, Corps District. Five dredged material disposal sites have interim designated status around the islands, three off Hawaii and one each off Guam and the American Samoas. All of the disposal sites are in deep water, of medium size, and at an intermediate distance from shore (see Table 19 for specifics). Type H of the sampling survey plan should be used for each of the Honolulu District disposal sites.

Surface sediments on the insular shelves are primarily calcareous sand and coral rubble, with a small amount of silt or mud (Chave and Miller

1976). The sediments on the shallow slopes and terraces are commonly littoral sands (pure or mixtures of detrital and biogenic calcareous grains) that have been transported downslope by mass movement (Fan and Grunwald 1971). Ocean floor sediments at water depths of 2,000 meters or greater contain little terrigenous input; the majority of deposited materials below 2000 meters are either of a pelagic biogenic origin (Neighbor Island Consultants 1977) and presently exist in the form of siliceous oozes or those brown clays typical of deeper aspects of the Pacific Ocean (Shepard 1963). Interspersed through the deep superficial sediment are found varying amounts of darker basaltic fragments and grains and products of past volcanic activity.

Table 19
Characteristics of Pacific Ocean Disposal Sites

<u>SITE</u>	<u>DEPTH</u> m	<u>AREA</u> n mi ²	<u>DISTANCE</u> n mi	<u>SURVEY</u> TYPE
Kauai-Hanapepe	1554	0.8	3.6	H
Kauai-Nawiliwili	851	0.8	3.6	H
Honolulu Harbor	501	0.8	3.9	H
Guam-Apra	1995	0.8	3.7	H
American Samoa-Pago Pago	2012	0.8	3.8	H

PACIFIC COAST

Thirty-one of the interim dredged material disposal sites have been assigned to those four Corps Districts along the Pacific seaboard: Los Angeles, San Francisco, Portland, and Seattle. The California disposal sites, especially the southern ones, are much deeper than those of Washington and Oregon, whereas all of the sites vary in size from small to medium and show an average area value of 0.30 square nautical miles. U.S. EPA (1976a) reports ocean disposal of dredged material by these Corps Districts to have been approximately $11.1 \times 10^6 \text{ m}^3$ in 1974 and $7.9 \times 10^6 \text{ m}^3$ in 1975.

LOS ANGELES DISTRICT

The Los Angeles Corps District ocean dumps the smallest amount of dredged material along the Pacific coast of the continental United States. Five disposal sites are situated within its limits. Each of these sites encompasses 0.8 square nautical mile and four of the five sites show water depths in excess of 100 meters (see Table 20). These physical characteristics suggest the need for two types of the sampling plan (Types E and H) to be used in survey operations.

Table 20
Characteristics of Los Angeles Disposal Sites

<u>SITE</u>	<u>DEPTH</u> m	<u>AREA</u> n mi ²	<u>DISTANCE</u> n mi	<u>SURVEY</u> TYPE
San Diego-Pt. Loma	86	0.8	8.2	E
San Diego - 100 fm	168	0.8	7.4	H
Newport Beach	457	0.8	4.3	H
Los Angeles	195	0.8	5.2	H
Port Hueneme	366	0.8	3.9	H

As a general rule, sediment cover off southern California is patchy and thin on banks and shelves (i.e., both insular and coastal) while being relatively thick in deep basins (Gorsline 1975). Existing surficial sediments on the continental shelf tend to be shallow detrital sands containing various amounts of organic and authigenic sand-sized material (Moore and Shumway 1959). The outermost portion of the shelf and the adjacent slope reveal sandy silts that grade to fine silts seaward. Submarine canyons and their associated fans are the major sources of sediment input for the deeper basins; those basins near the coast have thicker fill and more developed canyon-fan systems than do the distant outer basins.

Saucier projected that the Los Angeles Corps of Engineers would have an annual average dredging requirement of $2.5 \times 10^6 \text{ m}^3$ for the years

1974-1976. Of that total, approximately 1.4×10^6 m³ would be in the form of maintenance work (Pequegnat et al. 1978).

SAN FRANCISCO DISTRICT

On an annual basis, the San Francisco Corps District disposes of the second largest volume of dredged material among those Districts of the Pacific coast. Eight of the interim oceanic disposal sites fall under this District's jurisdiction. Water depth at these disposal sites ranges from shallow to deep whereas their sizes are either small or medium (see Table 21). Physical characteristics which vary in such a manner necessitate using five of the seven different types of survey sampling plans to obtain those data deemed essential for impact assessment concerning ocean disposal of dredged material.

Table 21
Characteristics of San Francisco Disposal Sites

<u>SITE</u>	<u>DEPTH m</u>	<u>AREA n mi²</u>	<u>DISTANCE n mi</u>	<u>SURVEY TYPE</u>
Moss Landing - Pier	5	<0.01*	<0.05	A
Moss Landing - 100 fm	183	0.4	1.4	G
Farallon Islands	238	0.8	22.3	H
San Francisco Channel	11	1.2	6.8	B
Noyo River	24	0.05	1.4	D
Humboldt Bay Harbor	21	0.02	1.3	D
Crescent City Harbor	27	0.2	1.1	D
Crescent City - 100 fm	183	0.2	10.0	C

*At present, only a point with no radius given

Surficial sediments on the continental shelf off San Francisco Bay are predominantly shell sands and glauconitic sands, while sediments on the adjacent slope range from fine sands through coarse silts to fine silts (Bailey 1966). Along the central coast, shelf sediments are generally shallow, and in many locations off California the surface

sediments are bound into nodules which are comprised of fine sand, shell fragments, and animal tubes bound together with a phosphate cement. Dispersed grain-size distributions in the vicinity of the Farallon Islands show that 50 to 80% of the sediments are finer than 0.06 mm, the division between very fine sand and coarse silt (U.S. Army Engineer District, San Francisco 1975). Such sediments are much finer than those from the San Francisco Channel Bar.

The average annual dredging requirement for the San Francisco Corps of Engineers has been projected to be approximately $7.7 \times 10^6 \text{ m}^3$ for the calendar years 1974 to 1976 (see Saucier's Table 1 in Pequegnat et al. 1978). Of the above total volume, $5.6 \times 10^6 \text{ m}^3$ would be the annual average for maintenance dredging.

PORTLAND DISTRICT

The Portland Corps of Engineers District has the largest dredging requirement of all the Districts along the western seaboard. Seventeen of the interim oceanic disposal sites fall within its jurisdiction. Most of the disposal sites are near the shore and all are small in size, but water depths at the sites are about equally distributed between the shallow and the intermediate categories. Table 22 lists the physical characteristics for each site and indicates the type of sampling survey plan recommended for that site.

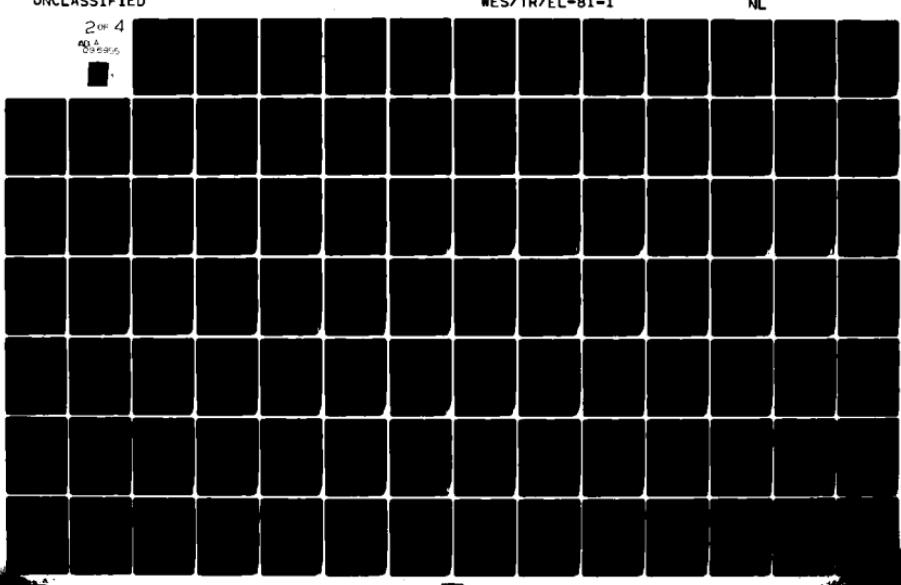
Surface sediments on the nearshore shelf of the Pacific Northwest are primarily sands consisting of detrital quartz and feldspar. This sand zone extends from the shoreline out to a water depth of about 40 meters off the northern and central Oregon coast. Off southern Oregon the sand forms a narrow belt along the coast in generally shallower water. Seaward of the sand zone the sediment consists of patches of mixed sand and mud, modern mud, and exposures of bare rock (Kim and Fowler 1970).

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Approximately $12.6 \times 10^6 \text{ m}^3$ of material was the annual average Portland Corps of Engineers dredging requirement for 1974-1976 (see Table 1 in Pequegnat et al. 1978). Maintenance work would account for about $11.7 \times 10^6 \text{ m}^3$ of that annual volume.

Table 22
Characteristics of Portland Disposal Sites

SITE	DEPTH m	AREA n mi ²	DISTANCE n mi	SURVEY TYPE
Chetco River Entrance	22	0.1	0.7	D
Rogue River Entrance	20	0.2	1.2	A
Port Oxford	15	0.03	0.6	A
Coquille River Entrance	20	0.13	0.9	A
Coos Bay #1	20	0.14	1.6	A
Coos Bay #2	24	0.15	1.7	D
Umpqua River Entrance	23	0.1	1.2	D
Siuslaw River Entrance	21	0.04	0.9	D
Yaquina Bay	18	0.05	1.2	A
Depoe Bay #1	5	0.03	0.05	A
Depoe Bay #2	24	0.03	0.5	D
Tillamook Bay Entrance	29	0.14	1.3	D
Columbia River #1	25	0.1	4.9	D
Columbia River #2	20	0.1	4.0	A
Columbia River #3	40	0.03	5.3	D
Columbia River #4	16	0.04	1.5	A
Columbia River #5	34	0.1	4.6	A

SEATTLE DISTRICT

The Seattle Corps District has been assigned only one of the interim oceanic dredged material disposal sites, possibly due to the fact that portions of the material are disposed in the waters of Puget Sound and the Strait of Juan de Fuca. In addition, some of the dredged sediments have very high biochemical oxygen demand (BOD) levels and are thought to require land disposal (Pequegnat et al. 1978). The Seattle disposal site is located in shallow water within the 12-mile contiguous zone (see Table 23). The dimensions of the site are such that Type B of the survey sampling plan should be utilized by the Seattle Corps District.

Table 23
Characteristics of Seattle Disposal Site

<u>SITE</u>	<u>DEPTH</u> m	<u>AREA</u> n mi ²	<u>DISTANCE</u> n mi	<u>SURVEY</u> <u>TYPE</u>
Willapa Bay	11	3.5	3.5	B

As previously mentioned, surficial sediments of the nearshore zone on the Pacific Northwest continental shelf are primarily sands consisting of detrital quartz and feldspar. Off the Washington coast this sand zone extends seaward to a depth of 50 meters or more where it is bounded by patches of mixed sand and mud, modern mud, and exposures of bare rock (Kulm and Fowler 1970).

The Seattle District dredges on the order of 1.7×10^6 m³ a year with much of the material being placed in upland areas or discharged in deep water in Puget Sound. Pequegnat et al. (1978) report that within a year or so Grays Harbor will be the site of a major project that will generate a planned 12.2×10^6 m³ of dredged material, some of which is expected to be disposed of in deep water off the coast.

ALASKA DISTRICT

This Corps District has jurisdiction over three interim dredged material disposal sites in the vicinity of Anchorage and Nome. The disposal sites are all small in size and located within three miles of the shoreline (see Table 24). Two of the sites are in shallow water while one is within intermediate depths; these sites need Types A and D of the survey sampling plan outlined in Chapter V of this report.

Table 24
Characteristics of Alaskan Disposal Sites

<u>SITE</u>	<u>DEPTH</u> m	<u>AREA</u> n mi ²	<u>DISTANCE</u> n mi	<u>SURVEY</u> TYPE
Anchorage Harbor	22	0.14	0.4	D
Nome - East Site	5	0.40	0.4	A
Nome - West Site	5	0.34	0.4	A

Surficial sediments of the Bering Sea follow a general bathymetric pattern according to Shor (1966). The continental shelf is covered with sand which grades to silt sizes near the slope, whereas the deep basins are covered by clayey diatomaceous oozes.

The annual average Alaska Corps of Engineers dredging requirement for 1974-1976 was about 0.4×10^6 m³ (see Table 1 in Pequegnat et al. 1978). Less than half of that volume (0.15×10^6 m³) resulted from maintenance dredging operations.

PART 2. THE SAMPLING PROGRAM

IV. SELECTION AND ELIMINATION OF VARIABLES TO BE MEASURED IN THE FIELD

GENERAL

Selection of the oceanographic variables or parameters that should be a part of the field survey of a dredged material disposal site, as well as those that should not be included, requires that consideration be given to the several uses that will be made of the data generated by the survey. The principal applications of the data that are discussed in this chapter include:

- a. First, the survey data must fill the needs of the environmental assessment and EIS required for final designation of the 130 interim ocean dredged material sites presently in existence.
- b. Survey data will be used to support applications for designation of new ocean dredged material disposal sites insofar as they satisfy the general and specific criteria for site selection.
- c. The data should provide the basis for carrying out a monitoring program and evaluation of impacts at appropriate intervals after site designation. To do this will require satisfying the analysis of effects set forth in Part 228.9 of the 1977 Regulations and Criteria.
- d. Finally, the data can be used to support requests by CE that EPA review and approve for issuance a permit to transport and dump dredged material in the ocean, as specified in Section 103(c) of the Act. Data, therefore, must meet some of the stipulations of Section 102(a) of the Act.

The stipulations of the Act and the Regulations and Criteria will provide the basis for selecting most of the variables to be measured in the field survey. These will be discussed in detail in ensuing sections of this chapter. Before that, however, it will be useful to set forth

the philosophy that undergirds both the selection of variables to be included and those not to be included in the survey. The 1977 Regulations and Criteria do not apply well to the survey problems associated with dredged material disposal sites, simply because most of these sites are small and located in shallow water close to shore. Indeed, as discussed on page 6, many parts of the Regulations and Criteria do not apply to dredged material at all.

SURVEY PHILOSOPHY

Oceanographic surveys can include a wide variety of measurements in biology, chemistry, geology, meteorology, and physics. The purpose of this chapter is to present an appropriate selection of those variables that will contribute most to preparation of a sound EIS for site designation or make a good impact-monitoring program or meet the criteria applying to the issuance of a dumping permit. Each unnecessary parameter included in the survey will take time and effort that can only boost costs unnecessarily.

Several guidelines have been established that have shaped the decisions in regard to the constitution of the survey. First, the designation of a disposal site does not assume that dumping has or has not had an effect on the biota within the site. The emphasis is placed upon preservation of the environment and its biota beyond the site boundaries. It follows from this that one must be concerned with movements of the water column that could carry some constituents of the dredged material beyond the boundaries of the legal site. This would seem to imply that a study of currents by means of current meter arrays must be called for, but such is not necessarily the case. Most present dredged material disposal sites are so shallow that water movements are determinable from wind, swell, and topographic data, all of which should be available from published sources. A limited amount of current meter work may be called for at many interim and new sites, as will be discussed later in this chapter. It should be pointed out

here, however, to those persons who may feel that currents should be studied at new sites in order to predict the movement of disposed dredged material, that there is a difference between currents and water circulation. The latter requires much more study to determine than the former. Yet it is the circulation flow which will carry that fine part of the dredged material prior to settlement or after resuspension by storms. Very likely only a year's study will yield data that will add much to the present conception of the typical flow on the continental shelf of a given region.

The second guideline is that the survey will place less emphasis upon the biota of the water column than upon that of the bottom. Physico-chemical data on the water column will characterize the site, define the mixing zone, and establish ambient levels of some pollutants. But no biological study of the water column is advocated because it is generally accepted that dredged material impacts here are minimal and transitory. Contrariwise, emphasis is placed upon studies of the sediments and benthos at appropriate distances from the disposal site. Except perhaps in the instance of very deep sites, dredged material will be distributed over the bottom with some immediate effects and with possible subsequent effects as it is moved by normal swell and currents or by the extraordinary conditions attendant to storms. Finally, selection of indispensable variables for the ocean survey has been guided by the regulations issued by the Council on Environmental Quality (29 November 1978, Federal Register) delineating the functions of an EIS and stressing among other things the importance of describing the process by which a permit-granting decision is reached by CE or EPA.

LEGAL AND REGULATORY REQUIREMENTS THE SURVEY WILL MEET

EIS PREPARATION FOR DESIGNATION OF INTERIM AND NEW SITES

The Council on Environmental Quality published in the 29 November 1978

Federal Register the final regulations implementing the procedural provisions of the National Environmental Policy Act (NEPA). Three parts of these regulations are directly related to the nature of the ocean survey to be recommended in this chapter. Related to EIS preparation, these are

- a. Emphasis upon alternatives including the proposed action. It is expected that the EIS will evaluate the environmental impacts of the proposal and all the alternatives. Therefore, the survey must determine what is present to be impacted.
- b. A succinct description of the affected environment. The area outside the disposal site that may be modified by direct and indirect effects of dumping.
- c. An analysis of significant impacts of the dumping and where appropriate supplying appropriate means of lessening adverse environmental impacts.

These considerations apply equally well to the EIS for selection of new dredged material disposal sites but, as will now be discussed, more elaborate guidelines must be followed, as promulgated in Part 228.6 of the 1977 Regulations and Criteria. Eleven specific criteria for site selection are presented in Part 228.6, but only some of them must be met by the ocean survey; others can be satisfied by data in available literature. Each criterion is listed in Table 25 together with a statement of whether or not it must be satisfied by survey or literature or whether both are needed. Only one criterion needs to be assessed by field work and another four may require some survey work as well as reference to the literature.

The parameters taken from the EPA criteria that will need field investigation are

- a. Bottom topography (moderate detail)

Table 25

Sources of Data to Satisfy Eleven Specific Criteria for Site Selection
 (Numbers in Parentheses are Same as in Regulations and Criteria)

<u>INCLUDED IN SURVEY</u>	<u>LARGELY FROM LITERATURE OR CHARTS</u>	<u>BOTH SURVEY AND LITERATURE NEEDED</u>
(7) Existence and effects of current and previous discharges and dumping in the area (including cumulative effects).	<p>(2) Location in relation to breeding, spawning, nursery, feeding, or passage areas of living resources in adult or juvenile phases.</p> <p>(3) Location in relation to beaches and other amenity areas.</p> <p>(4) Types and quantities of wastes proposed to be disposed of, and proposed methods of release, including methods of packing the waste, if any.</p> <p>(5) Feasibility of surveillance and monitoring (e.g., frequency of fog).</p> <p>(8) Interferences with shipping, fishing, recreation, mineral extraction, desalination, fish and shellfish culture, areas of special scientific importance, and other legitimate uses of the ocean.</p>	<p>(1) Geographical position, depth of water, bottom topography, and distance from coast.</p> <p>(6) Dispersal, horizontal transport, and vertical mixing characteristics of the area, including prevailing current direction and velocity, if any.</p> <p>(9) The existing water quality and ecology of the site as determined by available data or by trend assessment or baseline surveys.</p> <p>(10) Potentiality for the development or recruitment of nuisance species in the disposal site.</p> <p>(11) Existence at or in close proximity to the site of any significant natural or cultural features of historical importance.</p>

- b. Search for pollutant gradients (e.g., metals and possibly PCBs and chlorinated pesticides) from site into the environs, especially downstream, if determinable
- c. Depth of thermo-pycnocline and, if present, a quick determination of currents in two-layered system
- d. Physicochemical characteristics of the water column
- e. Assessment of the benthic biota, including undesirable bacteria in sediments

ESTABLISH BASIS FOR PROGRAMS TO MONITOR AND EVALUATE IMPACTS

Part 228.9 of the 1977 Regulations and Criteria (pp. 2483-84) allows establishment of a monitoring program that will provide the basis for evaluating the impact of disposal on the marine environment.

Nothing is said in the regulations as to when the program is to be instituted after site designation and how frequently it should be repeated. Clearly no blanket rule seems feasible, but the following factors should be taken into consideration when reaching a decision on these points:

- a. Whether the site is an interim one that has been used on a more or less regular basis or whether it is a new site
- b. How frequently the site has been used in the past or will be used in the future
- c. How much material is or will be dumped at the site in a period of one year
- d. The proximity of critical areas as stipulated in Section 102(c) of the Act
- e. The type of material to be dumped
- f. The recommendations of the original EA and/or EIS for the sites

Since the Register does not suggest the time between monitoring surveys,

the following schedules are recommended but are not to be considered mandatory. Institution of the monitoring program (which here includes impact evaluation) should occur in the case of an interim site one year after it has received final designation and should be repeated on an annual basis when the site is used regularly (e.g., monthly or lesser intervals), or one year after the most recent disposal when the site is used only occasionally (e.g., once a year or less). Because there is no past record, it is recommended that monitoring of a new site should begin six months after the first disposal and then on a yearly basis, as above. Not all of the oceanographic variables will be monitored, but only those of special concern in the specific area.

In selecting variables that should be included in the monitoring program, the authors have been guided by the possible results of the ocean disposal of dredged material. Obviously the monitoring program's success is wholly dependent upon a good baseline survey containing quantifiable data with a good degree of precision. The possible occurrences that the monitoring effort should note and evaluate are whether:

- a. Absence from the disposal site vicinity of biota characteristic of the general area.

This directive, as well as b. and e. to come, is concerned with impacts on the biota. Indeed, in reality all five are related either directly or indirectly with the welfare of the organisms around the disposal site. Realistically, it should be expected that the biota of the dredged material disposal site will be affected by the disposal activities. Thus, the major concern should be the effects on the biota of the extended impact zone (see Chapter I, page 12) and its environs. At the same time one should be aware of the fact that dredged material mounding may be attractive to some animal species. Structuring of an otherwise featureless level bottom may serve to attract both demersal finfish and large, mobile invertebrates such as lobsters and crabs.

Clearly to meet the intent of this directive will require careful sampling of the benthic biota. The selection of appropriate species must come, in most cases, if not all,

from the literature. This is difficult, simply because organisms are not equally sensitive to all pollutants. Moreover, the mere presence of, say, a toxic metal in sediment does not mandate that it is available to organisms.

- b. Progressive, nonseasonal changes in composition or numbers of pelagic, demersal, or benthic biota near the disposal site, when these changes can be attributed to the effects of materials disposed of at the site.

The emphasis here must be upon the bottom-living organisms: the demersal or bottom-feeding finfishes and the bottom-inhabiting invertebrate animals. Except under most unusual circumstances, the impacts upon pelagic life are transitory. Moreover, it is difficult to get quantitative data on most pelagic organisms. It is even difficult to sample benthic invertebrates quantitatively, at least to demonstrate progressive, nonseasonal changes in species richness or numbers of individuals. Here it seems imperative to deal primarily with the macrofauna and meiofauna, which can be sampled effectively with either a box corer or a grab. If conditions for trawling are satisfactory at the site, it is possible to take numerical samples of the macroepifauna with a beam trawl.

- c. Progressive, nonseasonal changes in sediment or water quality near the disposal site, when these changes are attributable to the effects of materials disposed of at the site.

Again, to meet the intent of this directive will require a good knowledge of sediments and their contents. In addition, it will be necessary to assess the levels of various nutrients and toxicants in the water column, especially near the bottom. Among the items to be analyzed are PCBs, petroleum hydrocarbons, DDT, and levels of such metals as Hg, Cd, Pb, and possibly Cu. The specific analyses to be run will depend on the dredged material disposed at the site.

- d. Dredged material has or has not moved into estuaries, marine sanctuaries, productive finfishery or shellfishery areas, or onto beaches or shorelines.

This will require baseline data on sediments as well as literature-derived information on winds, swell, and currents, including storm conditions. This will also require the locations of fisheries and a predictive model of the probabilities of dredged material transport to them and the probable effects if it did occur.

- e. Accumulation of contaminants, perhaps including human pathogens in marine biota near the site.

The intent of this directive is best met by chemical analysis of the tissues of an organism representing a high trophic level, e.g., a carnivorous fish or perhaps a detritivorous fish would be satisfactory. The analysis would search for PCBs, petroleum hydrocarbons, pesticides, and metals in an appropriate metabolic pool of the organism. Although the liver and/or fat tissues are frequently analyzed for the presence of these toxicants, muscle tissue is a better subject in that the organism cannot rid itself of the toxicant so easily from muscle as it can from fat and the liver. Because muscle usually constitutes a major part of the body structure of an organism, this tissue will permit storage of significant amounts of the pollutants.

SUPPORTING DATA FOR EPA APPROVAL OF DUMPING PERMIT REQUESTS

Some ocean survey data may be used to support requests by CE that EPA (Regional Administrators) review and approve for issuance of permits to transport and dump dredged material in the ocean, as specified in Section 103(c) of the Act. In reaching a decision as to whether or not to approve such permit requests, EPA can be expected to bring to bear those environmental considerations listed in Section 102(a) of the Act, to wit:

- a. The effect of such dumping on human health and welfare, including economic, aesthetic, and recreational values.
- b. The effect of such dumping on fisheries resources, plankton, fish, shellfish, wildlife, shorelines, and beaches.
- c. As noted above, the effect of such dumping on marine ecosystems, particularly with respect to:

- (1) the transfer, concentration, and dispersion of such material and its by-products through biological, physical, and chemical processes
 - (2) potential changes in marine ecosystem diversity, productivity, and stability
 - (3) species and community population dynamics
- d. The persistence and permanence of the effects of the dumping.
- e. The effect of dumping particular volumes and concentrations of such materials.
- f. Appropriate locations and methods of disposal or recycling including land-based alternatives and the probable impact of requiring use of such alternate locations or methods upon considerations affecting the public interest.
- g. The effect of alternate uses of oceans, such as scientific study, fishing, and other living resource exploitation and nonliving resource exploitation.

Obviously some of the above seven considerations were directed at materials having greater impact potentials than most dredged material. The principal ones related to the ocean survey are c, d, and e. But it should be noted in c, dealing with attributes of the marine ecosystem, that research efforts, not survey efforts, are called for.

THE OCEAN SURVEY PLAN: CONSTITUENT AND DELETED VARIABLES

GENERAL

The study plan presented in Part 228.13 of the 1977 Regulations and Criteria is not directly applicable to dredged material disposal sites. It was designed primarily to apply to disposal sites for municipal and industrial wastes, which are of relatively low density or have important constituents that are. It was expected that some constituents of most of the wastes involved were either toxic or would produce some deteriorative changes in the water column. Also, it was

expected to be applied to disposal sites that were by comparison large and located in deep water. For these reasons then, the 228.13 study plan places considerable emphasis upon biotal measurements in the water column and, because of size and depth, calls for the mounting of many stations and the taking of numerous discrete samples on the vertical axis.

If, then, the present recommended survey guide for dredged material sites seems too limited of scope by comparison, the reasons are related to the nature of most dredged material and the sites at which it is dumped. More specifically, it is expected that:

- a. Most dredged material has a high-density factor and will then sink rather rapidly through the water column. Moreover, those constituents that sink less rapidly, such as clay particles, will tend to accumulate at interfaces (e.g., thermoclines and haloclines) where their impact on the biota is minimal.
- b. Most dredged material dumped in the ocean is relatively nontoxic and in other ways relatively harmless to marine ecosystems. There are special exceptions to this statement, but such materials are generally dealt with in special ways.
- c. As noted in Chapter II, the majority of dredged material sites are small; hence, a small number of intra-site stations are required.
- d. The majority of sites are located in shallow water; hence, a small number of extra-site stations and vertical samples are required.

The variables or parameters appearing in Part 228.13 of the 1977 Regulations and Criteria and recommended for the survey are presented in Table 26; those that are not recommended are presented in Table 27. For the reader's convenience, all parameters, whether recommended or not, are discussed hereinafter in order of their appearance in Part 228.13(a-f) of the 1977 Regulations and Criteria.

Table 26
Oceanographic Variables Recommended for Inclusion in
Ocean Surveys for Site Characterization and Site
Monitoring of Dredged Material Disposal Sites

VARIABLES	SITE CHARACTERIZATION	SITE MONITORING
<u>Water Column/Pelagic Environment</u>		
Temp/Sal/Depth	All Stations	Center Station
Dissolved Oxygen	All Stations	and one each
Turbidity	All Stations	upstream and downstream
Contaminants		
Dissolved Hg, Cd, Pb, Cu	Center Stations	Center Station
High molecular wt. hydrocarbons	and proximal upstream station	and proximal upstream station
PCBs	"	"
Chlorinated pesticides		
Current meter	Site Center (repeat during survey)	Site Center (repeat during survey)
<u>Sediment Bed/Benthic Environment</u>		
<u>A. Sediment Characteristics</u>		
Gross bathymetry	Cover the Site and environs	Cover the Site and environs
Grain size & human debris	All meiofauna cores - 1st two macrofaunal cores	All meiofauna cores - 1st two macrofaunal cores
Total organic carbon (TOC)	All Stations	All Stations
Contaminants	All Stations	All Stations
Metals: Hg, Cd, Pb, and Cu		
High molecular wt. hydrocarbons		
Oil and grease		
PCBs		
Chlorinated pesticides		
<u>B. Biotal Characteristics</u>		
Macrofauna	All Stations	All Stations
Meiofauna	All Stations	All Stations

(continued)

Table 26 (concluded)

<u>VARIABLES</u>	<u>SITE CHARACTERIZATION</u>	<u>SITE MONITORING</u>
Macroepifauna	3 Stations 1 in and 2 outside	3 Stations 1 in and 2 outside
Bioaccumulation (tissues) 2 spp. for Hg, Cd, Pb, Cu, PCBs, petroleum hydrocarbons, pesticides	"	"
Bioaccumulation Introduced species	----	2 Stations
Trapped indigenous species (analysis of muscle for above contaminants and liver for enzymes - optional)		1 in and 1 control

Table 27
Variables Not Recommended for Inclusion in
Ocean Surveys for Site Characterization and
Site Monitoring of Dredged Material Disposal Sites

Water Column/Pelagic Environment

Contaminants

Metals: Extensive list in
Reg. & Criteria
Multiple, vertical stations
Extensive current meter survey
TOC
pH
Inorganic nutrients
Chlorophyll a

Biota

Zooplankton tows
night & day
Phytoplankton
water samples
Contaminants in zooplankton

Sediment Bed/Benthic Environment

Sediments

Mineralogy
Settling Rates
Contaminants
Metals: Extensive List

Biota

Microbenthos

ANALYSIS OF SURVEY PLAN

Timing (228.13a)

Scientists and environmental managers that TerEco sought for confirmation were of a mind that it would be sufficient to conduct two surveys per site prior to EIS preparation. Where there are marked differences in water temperature at a site, one survey should be done in the warm period and the other in the cold period. Where the site is influenced by substantial riverine flow, sampling should be done in the high and low water periods.

Duration (228.13b)

The ocean survey recommended in this guide can be carried out at most dredged material sites in 2 to 4 days, depending on size and depth.

Numbers and Locations of Sampling Stations

This is an important consideration that is discussed more fully in Chapter V. It is to be noted, however, that the minimum number of stations recommended for EIS preparation is six and the maximum is nine, but the number will have to be increased substantially when the extended impact zone expands toward a valuable resource.

MEASUREMENTS IN THE WATER COLUMN AT AND NEAR THE DISPOSAL SITE

Water Quality Parameters

Because temperature, salinity, and oxygen data can provide information on water flow, it is essential that the following variables be measured at all stations:

- a. Temperature-depth structure
- b. Salinity-depth structure
- c. Dissolved oxygen profile

Low dissolved oxygen values often occur naturally in bottom waters of the inner shelf in summer and fall; enough data should be on hand to clear DM as the cause.

The following variables should be measured only at the station nearest to the center of the site. (A discussion of the reasons for these chemical measurements is given under the section on "Chemical Contaminants in the Sediments" on pp. 96-100.)

- d. Trace metals
 - (1) Dissolved Hg (separate water sample)
 - (2) Dissolved Cd, Pb, and possibly Cu
- e. Other Annex I substances: PCBs, chlorinated pesticides, and high molecular weight petroleum hydrocarbons
- f. Turbidity measured as a profile from surface to the bottom. It may be necessary to carry out this investigation along the axis of the extended impact zone.

It is expected that most Corps Districts will have data on hand from past studies as to background levels of Section 227.6 substances. If not, this information must be obtained from other agencies or the open literature.

Measurement of temperature against depth, which is usually done by means of a recording probe system (STD), is required to ascertain the presence or absence of a thermocline (zone of maximum rate of decrease of temperature with increasing depth). This will establish the vertical thickness of the mixed layer, a consideration that is important to calculations of the limiting permissible concentration, as discussed

in Part 227.27 of the Regulations and Criteria. At most dredged material disposal sites the thermocline will be a seasonal (not permanent) one due to shallow depth. When coupled with salinity data, one may calculate changes of density with depth. Where density is increasing rapidly with depth a pycnocline is observed. This may correspond in position with the thermocline, since density of the open ocean is determined primarily by temperature. When density of the water column increases steadily from the surface to the bottom, it may be deduced that vertical movement and vertical mixing of the water and its constituents are minimal.

Measurements of dissolved oxygen (DO) are not as important as the above parameters, but determinations should be made especially near the bottom in sites that are used frequently. One might expect some temporary reduction of DO near the bottom if the dredged material was dumped recently and had a high biochemical oxygen demand (BOD).

Turbidity increases of a temporary type are always associated with the dredging/disposal process, especially as clay-size particles may remain aloft in the water column for long periods of time. It is well known, however, that some coastal regions have chronically turbid water near the bottom (the nepheloid layer), which is not associated with dredging. It is, therefore, important to obtain some baseline data on turbidity during an appropriate interval after dumping.

Sampling Requirements for Water Quality

Since the majority of dredged material disposal sites are very shallow, it will not be necessary to take many vertical samples for water quality determinations. The following guides may be followed:

- a. If the site is shallow and no seasonal thermocline is present and the column has about the same temperature at the bottom and at the surface (isothermal), then only one sample need be taken near the bottom.

- b. If the site is shallow and a seasonal thermocline is present, one sample should be taken just above the thermocline and one sample near the bottom.
- c. Sites of intermediate depth will require three samples, one above the thermocline, one in the thermocline, and one near the bottom.
- d. Deep sites will require the three samples for intermediate depths (as in c above) plus a fourth sample between the thermocline and the bottom sample.

Water Column Biota

Sampling of the pelagic biota in the water column is not recommended in this guide, simply because it is expected that it will suffer only transitory impacts from the disposal of dredged material. The density of the bulk of dredged material dumped in the ocean is so high that it moves quickly through the thermocline. Moreover, the water and its biotic contents impacted by a discrete disposal from, say, a hopper dredge, will soon move out of the area and will not be available for subsequent sampling. It is anticipated that available literature on the pelagic biota of regions containing ocean disposal sites will be sufficient for EIS preparation. Scientists consulted during preparation of the guide agreed that the pelagic biota cannot be quantified with sufficient precision to justify its use for monitoring. This applies particularly to the phytoplankton, the distribution of which is patchy in both time and space. Thus it is possible to obtain discrete phytoplankton samples in early winter that have a higher cell count than those of spring or early summer during a phytoplankton peak. This high uncertainty factor renders the phytoplankton useless as a quantitative monitoring tool. In some regards, however, there may be special reasons why it may be necessary to allocate some survey time to this parameter. For instance, there is continuing interest in the role that the dinoflagellate Ceratium tripos may play in the appearance of very low dissolved oxygen levels in the waters on the mid-Atlantic shelf. In such cases, it is suggested that one take an oblique net tow from below the thermocline to the surface near the center of the

site. Counts would then be made of the three most numerous species. It should be pointed out that Ceratium tripos is found along all U.S. coasts, where it may undergo blooms that are somehow related to lowered O₂ levels at the bottom.

MEASUREMENTS OF THE BENTHIC REGION

Gross Bathymetry

In order to sample some parameters effectively, the Chief Scientist must have at least cursory knowledge of the bottom topography in and around the site. This information can be gained with the ship's recording fathometer by crossing the site in a systematic way and plotting the results on graph paper (Figure 10).

Several tracks (probably 8) should be made across the site and environs more or less perpendicular to shore and to the axis of the longshore current. In the case of a site containing a particular topographic feature, the tracks should be made perpendicular to the axis of the topographic feature regardless of its orientation to the shoreline. On each pass the heading and estimated speed of the ship should be marked on each trackline. A good starting point would be a mile outside the site, as shown in Figure 10. The number of transects across the site proper will be dependent upon the degree of irregularity of the bottom. It matters little whether the site is square, round, or rectangular.

Grain Size and Human Debris Analyses

The grain size analysis as well as that for human debris (often referred to as artifacts) are very important parameters, particularly because they can be useful as monitoring tools. This means, however, that baseline data on granulometry must be taken during the initial survey of a new site. There is a need to be certain that the samples are

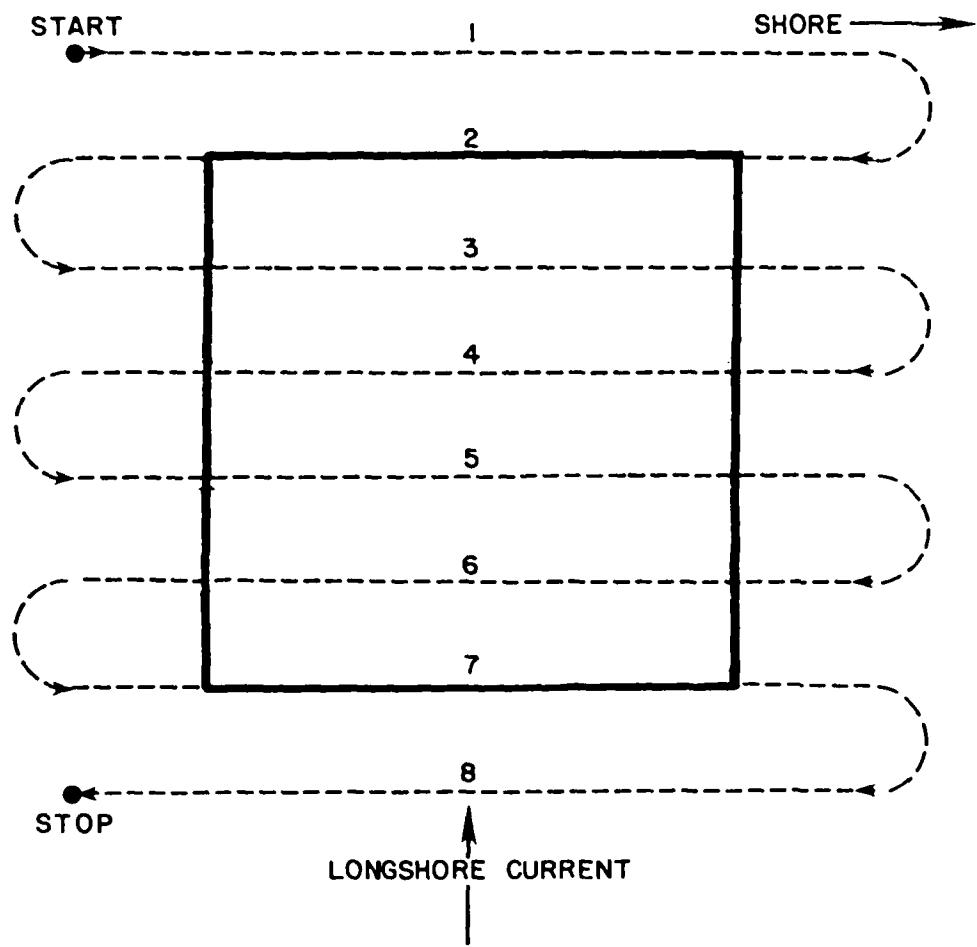


Figure 10. Sample path plan for fathometer tracks across disposal site

taken in a uniform manner. For instance, the length of the core that is used for granulometry can markedly affect the outcome of the analysis.

Part 227.13(b, 3, i) of the 1977 Regulations and Criteria states, regarding exclusions:

The material proposed for dumping is substantially the same as the substrate at the proposed disposal site.

It is believed that the framers of the regulations were primarily interested in the welfare of the benthic biota when this stipulation was laid down. Thus, the surficial sediments down to the depth of penetration of the bulk of the macroinfauna should be sampled. It is suggested here that an average depth of 10 cm is sufficient. It is probably true that in sediments that are predominantly clay most of the infauna lives in the top 5 cm and that they penetrate to 15 cm or beyond only when the sand component predominates. Again one is reminded that this study is not so concerned about granulometry inside the site boundaries as the contiguous area. An important part of the monitoring effort will be to trace, insofar as possible, the movement of dredged material from the disposal site, particularly if it is moving toward a critical area. To accomplish this will require that at least two 5-cm-long cores be taken from each box core at those stations leading from the site toward the critical area, such as an estuary. Movement of dredged material, if it can be traced at all, will be inferred not only from granulometric data but also from the presence of human debris materials (e.g., fly ash). In addition, it may be possible to trace sediment movement by gradients in certain metal contaminants known to be present in higher concentrations in the dredged material than in the receiving environments.

Chemical Contaminants in the Sediments

Metals. Although only two heavy metals, viz. Hg and Cd, are

mentioned in Annex 1 of the International Convention, it is advocated that four metals be investigated in the survey. Lead (Pb) is added because it is very toxic and because it gives one a tag on how much contamination of the sea bed is entering from the atmosphere (lead coming from the inclusion of tetraethyl lead in some motor fuels). A comparison between the lead content of the sediments of the disposal site and control area will offer some insights on this point. Several advisors have advocated analyzing sediments for copper (Cu) because of its ecological importance.

There may be divergence of opinion among scientific and regulatory personnel on how sediment samples should be prepared for metal analysis, but suggestion is made here that two methods be selected over the others. Since the major concern of metals in the sediment is whether or not a sediment-ingesting organism can mobilize the metals or the seawater can elutriate them, analyses to evaluate those two processes are preferred. The pH in the gut of marine invertebrates ranges usually from slightly acid to slightly alkaline and so a 0.1 N HCl leach is recommended. The short-term impacts of dredged material disposal can be estimated by seawater elutriation.

The other alternatives, total dissolution of the sediment with strong acids or a 1 N to 6 N HNO₃ leach, are not recommended because they are more likely to give a high reading based on total metal content of the sediment rather than the metals available to the ecosystem.

It is recommended that 80% of the sediment samples be treated by seawater elutriation and the remainder by 0.1 N HCl. The sediment samples for metal analysis will be removed from the box corer by means of hand-inserted plastic core liner tubing that has an i.d. (inside diameter) of 3.5 cm. Except in special cases a core length of 5 cm is recommended. A separate sample is required for Hg (at least 50 g); the other metals are analyzed from the second sample. Samples can be freeze dried with the understanding that this procedure may rally

metals into the elutriate that would otherwise remain inert.

Chlorinated Hydrocarbons - PCBs (Polychlorinated Biphenyls) and Pesticides. It is generally agreed that substantial release of these compounds from dredged material does not occur during disposal operations. It might appear, therefore, that seawater elutriation of these compounds should be adequate. However, most of TerEco's advisors have suggested that since it is difficult to monitor the longer term release of these contaminants from disposed material, it would be best to subject these samples to total extraction.

Samples should be removed from the box corer with a stainless steel tube (3.5 cm i.d.). Analysis will be primarily for Arochlor 1254 (PCB), p,p'-DDE, dieldrin, and chlordane. Other compounds may be added if, historically, they have been contaminants in the material disposed at the site.

Oil and Grease. The term "oil and grease" refers to the organic fraction in natural waters and sediments that is preferentially soluble in organic solvents. The extract contains many fractions that are neither oil nor grease; hence, some investigators prefer to label the material derived by the oil and grease extraction "total extractable matter." The oil and grease fraction in sediments may include fats, oils and waxes of vegetable or animal origin, hydrocarbons of natural origin, petroleum derivatives, organic chemicals, pesticides, detergents, soaps, and elemental sulfur. The plant and animal materials are not toxic and are generally subject to biodegradation; hence, their only impact, if any, may be BOD. These oils may produce floating sheens (as will petroleum oils) that can coat the epithelial surfaces of fish gills or may asphyxiate benthic animals when the floating globs encounter surface debris that eventually sinks to the bottom. Petroleum residues on the other hand may have long-lasting sublethal effects. When oil pollutants are incorporated in sediments below the aerobic layer, they can remain unchanged and toxic for long periods of time until bacterial degradation is complete. In some instances this

could alter the composition of the benthic community by killing off sensitive species.

High Molecular Weight Petroleum Hydrocarbons. The quantity of crude petroleum hydrocarbons entering the ocean today amounts to several million tons per year. Crude oils are a complex mixture of hydrocarbons ranging in molecular weight from that of methane to as much as 100,000. Crudes consist of three fractions - oils, resins, and asphaltenes. Of these, the present environmental concern centers on the oils, which are themselves constituted of alkanes, cyclo-alkanes, and aromatics. The aromatics have been included in the survey plan because of their demonstrated toxicity for both plants and animals. Whether from natural seeps, oil spills, or disposal operations, some high molecular weight hydrocarbons become incorporated into sediments where their residence time increases and their effects on the benthic biota are maximized.

The sediment samples for assessment of high molecular weight hydrocarbons should be removed from the box corer by either a glass or stainless steel coring tube.

Total organic carbon (TOC). The sediments of rivers, estuaries, and upper bays commonly contain high levels (4% organic carbon or more) of organic carbon washed down from terrestrial sources or salt marshes and sea grass beds. Since these are among the principal sites of navigable channels that must be dredged from time to time, it is not surprising that dredged material frequently contains substantial organic carbon loads. Characteristically, the percentage of organic carbon in sediments tends to drop at the mouths of bays and on the inner shelf. Hence, it is to be expected that if the organic carbon load of sediment dumped in ocean disposal sites is significantly higher than that in the sediment of the receiving environment, the material might have a substantial BOD and might at the same time encourage the development of some benthic organisms. Also, TOC could

serve as a tracer to check gross movements of dredged material after it has been dumped.

An inimical factor associated with high TOC values, particularly if municipal wastes are a contributing factor, is that they will contain elevated concentrations of ammonia.

Samples for TOC analysis should be removed from the box corer by means of glass tubes.

Benthic Fauna

Macroepifauna. The macroepifauna consists of those organisms, such as shrimps, lobsters, crabs, and demersal fishes, that live and/or feed on the surface of the sediments. Demersal fishes are those that swim in the water column but feed upon bottom-living organisms. It is obvious that many finfish and shellfish of commercial value belong to this ecological category - the macroepifauna. It is difficult to sample most species of the epifauna quantitatively. Certainly quantitative sampling cannot be accomplished with an otter trawl simply because it is impossible to calculate the area swept by the otter boards and the net. Nevertheless, data gathered by this type of trawl have descriptive value in what is called site characterization for EIS preparation.

It is recommended that the macroepifauna be sampled by means of a beam trawl having a 3-meter gape. The advantage of this device over the otter trawl is its fixed aperture that is held rigid by means of a steel bar (the beam). In practice it is suggested that the beam trawl be towed along the long axis (or diameter) of the site at a speed of 2 knots for a bottom time of 10 minutes for each tow. Two tows are recommended at each station. Theoretically, it would then traverse about 615 meters per tow while sampling about 1850 m^2 ($615\text{ m} \times 3\text{-m gape}$), which should be sufficient to obtain a representative sample of the epifaunal species at most sites. This procedure should be repeated

both upstream (perhaps 1 n mi away) and at stations located on a line with critical areas or human amenities. It is possible that no clear upstream-downstream aspects exist in the contiguous area (see discussion of currents that follows). In that event, the macroepifauna should be sampled only at a station or stations toward the shore or toward a special critical area.

The following uses are to be made of the macroepifaunal samples in both the baseline and monitoring cruises:

- a. A simple determination of the gross wet-weight biomass of the macroepifauna has considerable merit, particularly as a part of the monitoring program after baseline values have been established. To simplify this process, it is suggested that the catch of the macroepifauna in the cod end of the beam trawl be placed into a mesh bag and weighed by means of a reasonably accurate hanging produce scale.
- b. Simple species richness should be determined, i.e., the number of species of each type (finfish, shellfish, gastropod, bivalve, etc.) per estimated area covered or time involved (effort) for each haul.
- c. The sorting, as close to species determinations as feasible, may be done aboard the ship, or the entire sample (except as noted below) can be preserved. In either event, representatives of each species should be preserved for precise laboratory identification.
- d. Two species should be selected, preferably a demersal fish (e.g., flounder or other flatfish) and a shellfish such as a crab, lobster, or large bivalve, and frozen in plastic sacks for metal analyses. Individuals of the same species used for metals should be wrapped individually in treated aluminum foil and frozen for PCB, chlorinated pesticide, and petroleum hydrocarbon analyses. All specimens used for metal analysis or other methods of analysis should be kept and preserved for species verification.

Macrofauna. These organisms are defined by being over 0.5 mm in length and by living in the sediment bed. Among the principal taxonomic groups of the macrofauna in marine sediments are poly-

chaetous annelid worms and bivalve mollusks. It is possible to quantify the populations of the predominant macrofaunal species at a given station. But to do so requires that the samples be taken with a good box corer or, possibly, a Smith-McIntyre grab. But sufficient samples must be taken at each station to establish sampling precision. Also, the length of the core should be uniform throughout. As noted above with granulometry, the core need not be more than 10 cm long.

Based on the work of Saila et al. (1976) and McIntyre (1971), among others, it is advised that five box cores or grabs per anchor station should account for most of the within-station variance. If for some reason the number of cores per station has to be reduced to, say, three, the number of stations should be increased proportionately to give the same number of samples for analysis.

The five most abundant species will very likely account for at least 85% and possibly as much as 95% of the biomass of the infaunal species. The following determinations are recommended for the macrofauna:

- a. Determine species richness, as for macroepifauna.
- b. Determine numerical abundance. As mentioned above, the most abundant groups will likely be led by polychaetes, bivalves, amphipod crustaceans, and occasionally sipunculid worms.
- c. Separate the two most abundant species groups and identify all individuals to species.

Meiofauna. These organisms are defined as being between 0.5 mm and 0.062 mm in length and living in the sediments. Thus, the smallest of them are equivalent in size to a 4-phi sediment grain, which lies between fine sand and coarse silt. Accordingly, these organisms have a very intimate dependency upon the condition of the sediment and the constitution of the interstitial water. Although use of meiofaunal studies in environmental regulatory monitoring programs is new, they may assist in interpreting data on more commonly studied groups such

as macroinvertebrates. Until a broad data base on meiofauna is developed, conclusions drawn directly from meiofaunal studies should be supported by data from more traditional studies of macroinvertebrates. Inclusion of the meiofauna in the ocean surveys follows the 1977 Regulations and Criteria (Part 228.13(e) (4)). The group can provide a solid monitoring tool. The advantages of working with the meiofauna are

- a. They can be sampled quickly, even by hand-held corers operated by divers.
- b. Only two species groups are sufficiently abundant to be dealt with in sample analysis. These are nematodes and harpacticoid copepods.
- c. Fairly reliable quantification can be achieved by technicians after a brief training period.
- d. Sampling of these organisms, requiring two samples per grab, is such that samples for metals, pesticides, PCBs, high molecular weight petroleum hydrocarbons, etc., can be taken from the same grab.
- e. They are predictably responsive to major shifts in grain size, e.g., nematode populations increase dramatically when sand attains values of 60% or more of sediment by weight.
- f. It is possible that some meiofaunal components which are influenced by sediment pollutants are engulfed either directly or indirectly (via one or more species of macro-infauna) by a species used as food by man.

Two meiofaunal samples (well spaced) are taken from the meiofaunal grab or box corer at each station by means of 3.5-cm (i.d.) plastic tubes. Only the top 5 cm of the core are retained for analysis. In practice all tubes are emplaced together in the sediment of the grab or corer before any major disturbance of the surface occurs. Thus, the following tubes may be involved:

- a. Meiofauna - 2 tubes, plastic
- b. Granulometry and human debris - 2 tubes, plastic

- c. Metals - 2 tubes (1 for Hg, 1 for other metals)
- d. PCBs, etc. - 1 tube, stainless steel
- e. Petroleum hydrocarbons - 1 tube, stainless steel

This totals 8 tubes with a combined area of about 90 cm². There are 900 cm² in a 30-by 30-cm box corer so there is enough room to space the samples evenly so they do not interfere with one another.

OTHER MEASUREMENTS

Hydrodynamic Features

The following measurements are to be made while the vessel is anchored, both fore and aft when feasible, and very likely at the center of the site.

Wind and Swell.

- a. Estimate the direction and speed of the wind. One station is sufficient, but observations should be made at least twice during the sampling regime.
- b. Estimate the height, speed, and direction of the swell. Note these relationships with wind speed and direction. Throughout the survey, note the relationship between wind, swell, and chop. Also, time the period of the wave, i.e., the time between the arrival of wave crests at the vessel.
- c. Estimate from the tide chart the tidal stage at the time the wave observations are made. Also, this information will be vital to an understanding of the current regime. Note differences in water movements, if any, when the tide changes.
- d. Look for surface manifestations (e.g., slicks) of internal waves and their period.

Currents and Water Mass Movements.

- a. Using a deck-readout current speed and direction meter determine the nature of the current near the bottom. If

the water column is two layered, as noted by the presence of a discontinuity such as a thermocline or halocline, then record the current between the surface and the discontinuity and near the bottom. If the site is relatively shallow (10-20 m), note whether or not the current meter surges shortly after passage of a wave crest at the ship. The effects of wind chop will not ordinarily be detected at the bottom, even in shallow water, but swell that travels from considerable distances at high speeds will. A rule of thumb states that a swell will disturb the bottom if the depth is not much greater than the wave length. Also, note the color of the water; if it is turbid, check the distribution of the turbidity with vertical hauls of a transmissometer. Attempt to ascertain whether the turbidity is due to some extrinsic source, such as river flow, or from swell disturbance of the bottom. Current measurements should be made upstream and downstream as well as in the site.

- b. Note the movement of the upper meter or so of water by discharging a series of fluorescent dye packets (available at a marine hardware). Time their movement, and plot their direction of flow against that of wind and swell. One can use the survey vessel to advantage since its length at the water line will be known; hence, the speed of surface flow can be determined by timing the movement of dye from end to end of the vessel.
- c. It may be necessary to verify mass flow of water by deploying one or more small drogues or expendable current probes. Follow for a sufficient time to establish the circulation past the site. Consider deploying two drogues outside the site (upstream and downstream, if known) and one in the center of the site.
- d. If it has not already been done, profile the water column by means of an appropriate conductivity-temperature-dissolved oxygen-depth probe (CTD) in order to determine the temperature-depth and other characteristics of the water column.

Bioaccumulation and In Situ Bioassays

Bioaccumulation may be defined as the taking up and storage by an organism of a nonfood compound until it reaches concentrations above those in the ambient environment, including the storing organism's food (Figure 11). It is apparent, then, that one is investigating bioaccumulation when, as specified above, analyses of various tissues

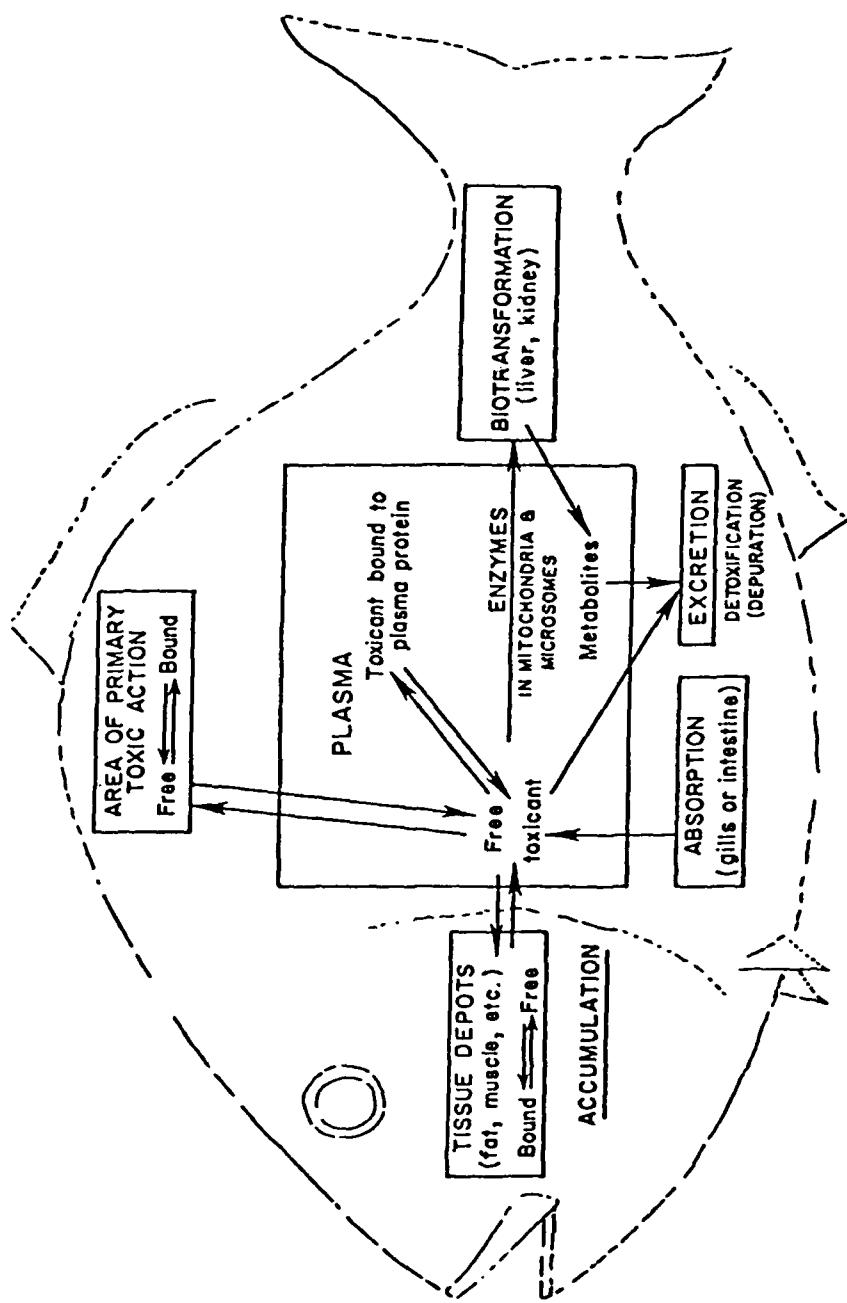


Figure 11. Bioaccumulation and processes influencing the amount of a toxicant reaching the site of its primary toxic action. Modified from Fingl and Woodbury (1965)

for trace metals, PCBs, petroleum hydrocarbons, etc., are carried out. Unfortunately, this action leaves some doubt as to where the organism picked up the contaminants, if any; what its normal body burden is; and how long it takes to accumulate a toxicant to above ambient levels. Finally, and perhaps most important of all, it does not really reveal whether the organism is stressed by this accumulation. Bioaccumulation can be determined by the technique of either laboratory or field bioassays.

Field Bioassays. Bioaccumulation is a matter of concern to environmental managers not alone because it is stipulated in the ocean disposal criteria, but also because it is often linked with chronicity. As an organism acquires sublethal burdens of a toxicant in one or more of its tissues, the effects are likely to result in chronic changes in growth, reproductive capacity, behavior, or general health. These subtle changes in the organism can be detected by assaying certain metabolic enzymes before the time that burdens are large enough to result in death. Provided with this information, the environmental manager can act to modify dumping operations to alleviate the impacts. Methods are now available for conducting bioassays in the field where the test organisms are more likely to obtain impacts from natural foods and ambient waters. Cages are now available that will capture indigenous species after beginning the test and will hold them apart from indigenous species that were captured prior to the test and permitted to depurate (cleanse metabolically) themselves of the contaminant of interest. Another great advantage of the field bioaccumulation study of this type is that it permits use of large, mobile epifaunal species as test organisms.

One basic advantage of the use of large species is that one has a large enough sample to utilize muscle tissue for accumulation. This can be significant. There are various places in the body of organisms where contaminants may lodge. Obviously the liver is such a metabolic pool, but this would be expected because, as is shown in Figure 11, it

transforms many contaminants, often into harmless materials that are excreted. Fat soluble contaminants, such as DDT, may be deposited in fat (adipose) tissue, where they remain until the fat depot is called upon as an energy source. Both the liver and adipose tissue are relatively unimportant metabolic pools, not alone because contaminants are quickly rallied from them, but also because man does not for the most part eat these tissues from crabs or fishes. Much more important is muscle tissue, which man does eat. This is a metabolic pool that is slow to accumulate and slow to give its burden up. Whereas it is difficult to get effective muscle samples from polychaete worms, it is not from a fish or a crab.

The units for conducting these field tests should be deployed (1) in the site, (2) at a reference site, and (3) if there is a flow from a contaminated river or embayment discharge, at a control site (see Figure 12 and caption for further explanation). They should be retrieved after 96 hours or more and the organisms prepared for analysis.

Enzyme and Adenylate Energy Charge Analyses. It is important in effective bioassay and bioaccumulation studies to assess both acute and long-term effects. Long-term effects on such things as reproduction, behavior, or metabolic processes are by their very nature difficult to assess directly by usual field methods. One way to evaluate long-term effects is through studies of enzymes affected by particular constituents such as petroleum hydrocarbons, trace metals, and PCBs. This involves laboratory assays of cytochrome P-450 for petroleum hydrocarbons, catalase for trace metals, and ATPase for PCBs. In addition a relatively new and potentially useful measurement is the adenylate energy charge system which can be used to test for the general health level of the organism. It should be pointed out that these are indeed sensitive tests, but this does not mean that they are overly protective of the environment. Let it be understood that bioaccumulation per se is a normal function of organisms and thus the accumulation of even contaminants need not be particularly stressful upon the organisms.

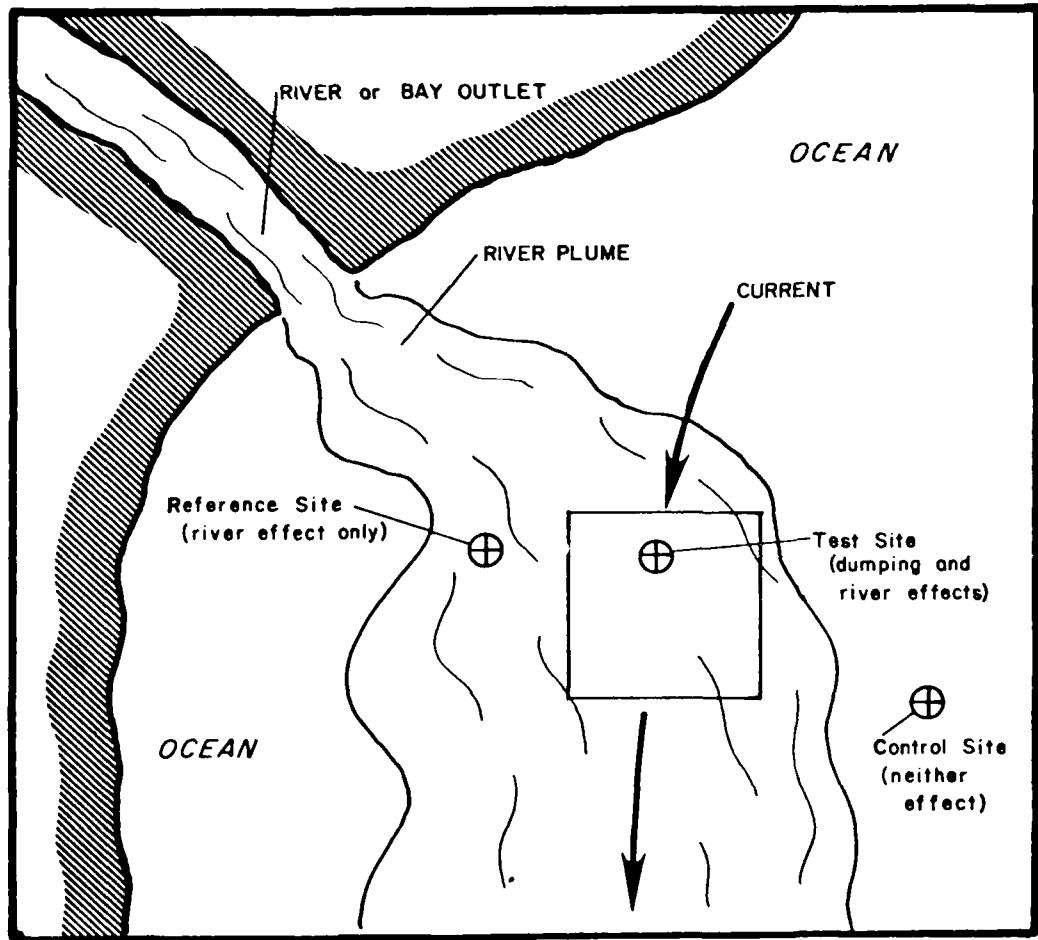


Figure 12. Diagram showing the relationship among the Reference Site, Test Site, and Control Site when a polluted river flows over a dredged material disposal site. The reference site is the control for the test site, since the tested variable difference is the dumping. The control site per se is the control site for the reference site where the test variable is the polluted river flow in the ocean

When properly carried out, metabolic enzyme analyses can gauge to what extent, if any, the organism is suffering sufficient stress from accumulation to develop chronic symptoms. Caution must be exercised, however, when interpreting these results, because research has only recently begun to develop a data base for species commonly tested with dredged material. This system is important to the permitting process and also to establishing a bench mark for future periodic evaluation of disposal impacts and monitoring programs.

V. SAMPLING STATIONS

INTENT OF SAMPLING PLAN

The sampling strategy for dredged material sites must meet two criteria: site designation and impacts monitoring. Section 228.4(e)(1) of the ocean dumping criteria specifies that the designation of dredged material sites will be based on environmental studies of the site, regions adjacent to the site, and on historical knowledge of the impact of dredged material on similar such sites. Section 228.9 defines the purpose of the monitoring program as evaluating the impact of disposal on the marine environment by referencing the monitoring results to a set of baseline conditions. Moreover, the baseline or site designation survey should be regarded as the first of a series of studies to be continued as long as the site is used for waste disposal (Section 228.13). Thus the site designation and monitoring surveys must be similar in their scope, and they must consider and reference both changes in time and changes between the site and environs.

Based on the historical knowledge as to the kind and extent of impacts emanating from ocean disposal of dredged material and the fact that most of the 130 interim sites have been used regularly or at least intermittently for many years, it is possible to refine the shotgun approach of impact assessment down to a few variables and selected locations which are most indicative of impacts from dredged material disposal. The basic sampling strategy is to examine those locations where impacts are most likely, least likely, and with greatest potential for adverse consequences. In practice, sampling stations will be located upstream of the site where impacts are least likely, inside the site where impacts should be most severe, and downstream of the site where migration of materials or contaminants out of the site into

adjacent areas is of concern. Superimposed on the basic sampling plan are the secondary factors affecting the sampling strategy. The secondary factors, which are site specific, will tailor the sampling strategy to the site's specific environs.

PHYSICAL CONSIDERATIONS

Compared to other ocean disposal sites, the dredged material sites, as a group, differ in two respects which affect the size of the sampling plan. Generally, dredged material disposal sites are small in area and of shallow depth. This is not to imply that there are no dredged material sites as large or as deep as those used for other types of ocean disposal, but these are the exception rather than the rule.

Therefore, a basic sampling plan must be developed which is applicable to the different kinds of dredged material disposal sites, i.e., different on the basis of depth and area. Toward this end a generic classification of the dredged material sites into applicable categories based on depth and area has been put forth (Chapter II). This classification is not intended as a rigid prescription for designating the number of sampling stations at a particular site. But rather, it is intended to provide a common basis for a starting point in the sampling strategy to be developed for each site. The sampling plan for each particular site is to be developed on a site-specific basis after consideration of the secondary factors influencing sampling strategy which will modify or add to the basic sampling plan for that particular type of site (type of site being a function of depth and area).

The frequency distributions of the 130 dredged material sites by depth and area are shown in Figure 13. The sites can be divided into three more or less natural groups of small ($\leq 0.5 \text{ n mi}^2$), medium ($> 0.5-3.9 \text{ n mi}^2$), and large ($\geq 4 \text{ n mi}^2$). Such a grouping accounts for approximately one half of the sites in the small category and one half in the medium category, with only about 10% of the sites in the large category.

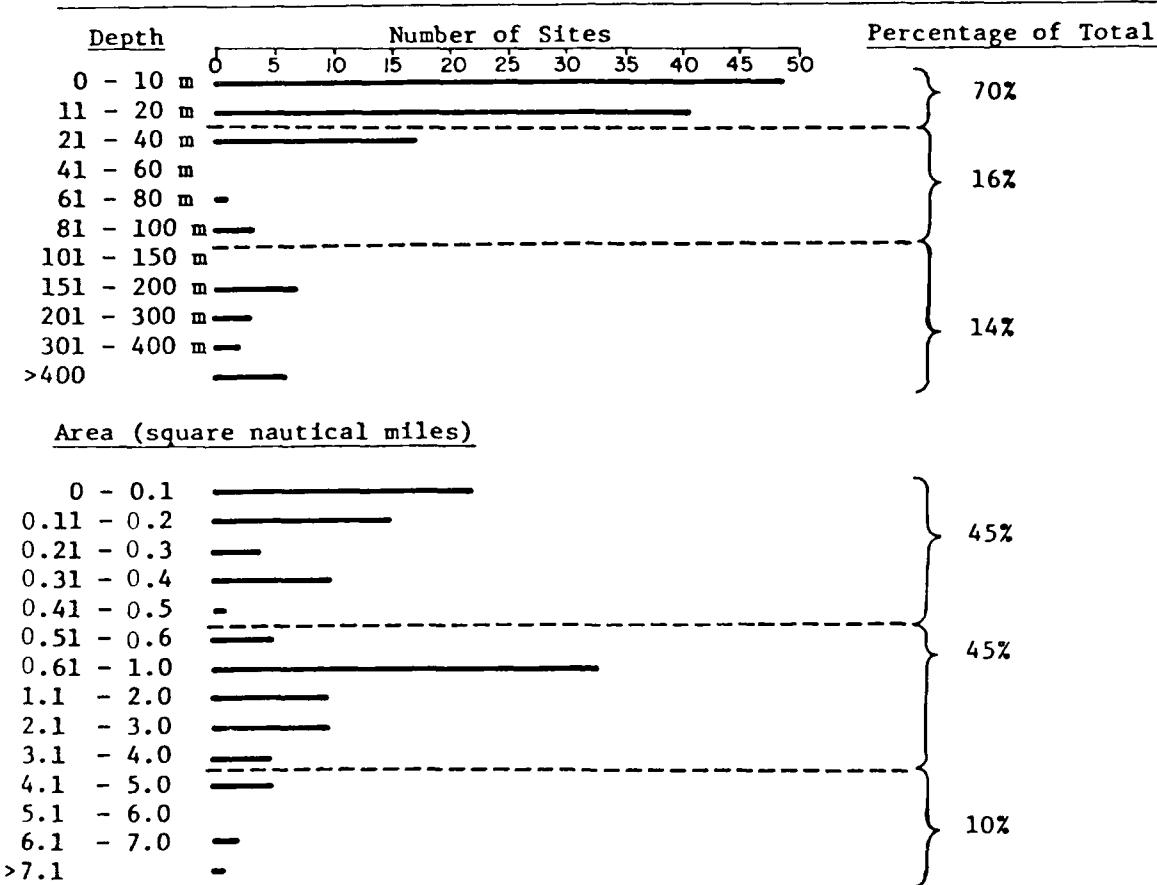


Figure 13. Frequency distribution of dredged material sites by depth and area

Similarly, although not nearly so obvious, the sites can be divided by depth into three groups. The shallow category, accounting for approximately 70% of the sites, is limited by a depth of 20 meters or less. Twenty meters was chosen as the break point because it is the maximum depth to be considered in calculation of the limiting permissible concentration in the permit application. Thus these sites essentially lie within the mixing zone. The intermediate category ranges from 21 to 100 meters. These 16% of the sites are fairly evenly spread over the depth range and they are still relatively easy with regard to sampling difficulty. The deep category (those over 150 meters) accounts for about 14% of the sites. Because of water depth, difficulty in sampling, special gear requirements, and the use of large survey vessels can be expected.

GENERIC CLASSIFICATION

From the depth/area considerations the dredged material disposal sites may be classified by type in order to select the basic sampling strategy applicable to a particular site. This classification is presented in Table 28. For the purpose of reference only and not for rigid designations from which deviation is not possible, the sites are classified as Types A through I.

Moving down in the matrix (i.e., increasing area) represents the need for greater areal coverage within the site. Hence, survey costs will be greater by virtue of the increased number of samples. Similarly, increasing depth (moving to the right in the matrix) represents an increasing cost by: an increase in the difficulty of sampling, an increase in the number of water column samples, and an increase in the number of sampling stations downstream of the site. Type A sites (also being most common) should be the simplest and least expensive sites to study, and Type H sites will likely prove to be the most expensive and most difficult.

Table 28
Generic Classification of Dredged Material
Disposal Sites by Area and Depth

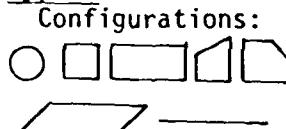
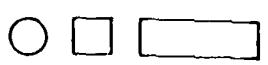
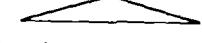
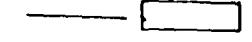
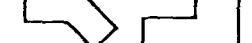
AREA	DEPTH		
	Shallow ≤ 20 m	Intermediate 21 - 100 m	Deep ≥ 100 m
Small ≤ 0.5 n mi ²	Type A 43 Sites	Type D 12 Sites	Type G 2 Sites
Medium 0.6 - 3.9 n mi ²	Type B 36 Sites	Type E 7 Sites	Type H 16 Sites
Large ≥ 4 n mi ²	Type C 10 Sites	Type F None	Type I None

SAMPLING STATION SELECTION AND ORIENTATION

The very nature of the dredged material, the varying amounts dumped, and the frequency of disposal site use, as well as the biological/chemical/physical attributes of the site environs throughout the country, tend to preclude the formulation of a realistic sampling strategy applicable to all sites. If a single plan were based on the preponderance of sites, it would not adequately cover the deep or large sites. If it were based on the few exceptional sites, it would be much too intense and excessively expensive for the majority of sites; and if it were based on average depths and areas, it probably would not do justice to any site. These considerations notwithstanding, any sampling strategy cannot ignore site-specific variability in dredged material and site environments. Despite this site specificity, guidance is needed just as limitations have to be made on the variables to be included. A basic sampling plan will serve two purposes. Most importantly, it will lend a degree of coherence to the site designation/monitoring studies of the dredged material sites thereby facilitating intersite comparison and evaluation of impact; it will also provide Corps personnel with guidance in preparing a scope of work and in evaluating proposals for these projects.

The guidance deemed most useful to the Corps is in two parts. First, the general sampling plan is determined by depth/area considerations; second, the definitive sampling plan is refined or amended through a consideration of the secondary factors as they pertain to the specific site.

Using the same depth/area matrix in Table 28, the basic sampling strategy is shown in Figure 14 for the generic disposal sites (Types A through H). Also shown are the typical site configurations actually represented in each of the type sites. Configuration is an important

	Shallow	Intermediate	Deep
Small	Type A Configurations:  	Type D 	Type G 
Medium	Type B   	Type E 	Type H 
Large	Type C  	Type F NONE	Type I NONE
NUMBER OF WATER COLUMN SAMPLES			
	1*	2 - 3*	3 - 4*

* at one station within and one station upstream of the site

Figure 14. Site configurations and sampling station locations for generic disposal sites

consideration as it (and the other secondary factors discussed later) influences the orientation and number of sampling stations within the disposal site.

For Type A sites (shallow and small) two stations within the site confines, two stations upstream, and two stations downstream are considered to be the basis to which adjustments/additions can be made. This basic sampling plan will allow for a comparison of three areas: (1) clearly outside the influence of the disposal activity (upstream in the sense of being into the prevailing net current from the site), (2) in the area most likely to be influenced by the disposal activity (within the site), and (3) outside the disposal site in the area which is most likely to be affected should the material be moving out of the disposal site (downstream in the sense of being downcurrent from the site). Thus the three kinds of areas sampled are: the best (control or reference), the worst (in the site), and the most likely to show affects or movement outside the disposal site. The orientation of these sampling stations is shown in the hypothetical case in Figure 15.

Moving down the classification matrix (Figure 14) sampling stations are added within the site (3 medium, 5 large) to provide better spatial coverage. As the size of the site increases, the basic number of stations outside the site remains the same with increasing area.

The number of water column sampling loci are also shown in Figure 14. For those sites shallower than 20 meters (Types A, B, and C), a single sample within 1-2 meters of the bottom is most likely to show changes in contaminant concentrations in the water column due to the presence of dredged material.

Moving across the classification matrix to the sites of intermediate depth (Types D and E) additional sampling stations outside the site are not required; however, the number of water column sampling loci in-

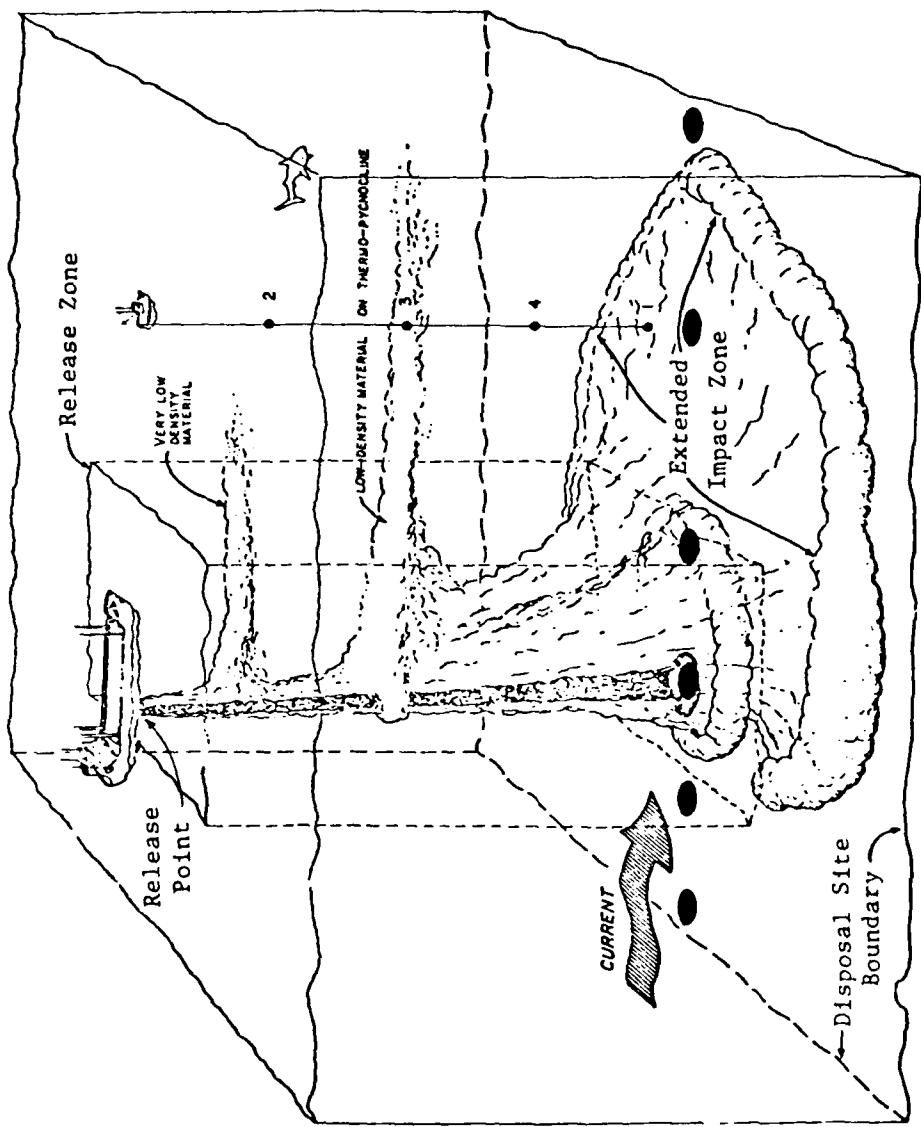


Figure 15. Stylized sampling plan at a small disposal site. ● denotes sampling stations. • denotes water column sampling points for contaminant analyses

creases to 2-3. Again, the primary locus is near the bottom and a second is recommended in the middle of the upper mixed layer. A third water column sample should be taken at the pycnocline if significant amounts of contaminated material are currently being dumped in the site.

At the deepest sites (Types G and H) a third sampling station is recommended downstream of the site in order to account for the possibility of dispersion of the material over a greater area outside the site bounds. There shall be three to four water column sampling loci, the number being dependent on the depth from the pycnocline to the bottom and the degree of contamination of the dredged material. One may wish to add more loci if the material is very contaminated.

The priority of water column sampling loci (1-4) is shown in Figure 15. It is also important to distinguish water column contaminant sampling stations from regular sampling stations. While contaminants in the sediments may justifiably be expected to show spatial differences within and around the disposal site, the extreme dilutive capacity and dynamic nature of the water column confound attempts at determining contaminant gradients in the water column. Thus, until such time as field studies indicate the need for a more intensive study, water column contaminants should be sampled only at two locations: one upstream of the site and one in the site.

SECONDARY FACTORS AFFECTING SAMPLING STRATEGY

Having determined the basic sampling strategy by the depth/area characteristics, the Corps Districts (or their consultant) must define the specific sampling plan in consideration of how the secondary factors affect the particular site. The secondary factors and their impact on the basic sampling strategy are discussed below.

SECONDARY FACTORS

1. Historical Data Base
2. Configuration
3. Orientation
4. Dumping Center
5. Depth Relief
6. Current Velocity
7. Adjacent Amenities
8. Proximity to Adjacent Sites

Historical Data Base

For many of the dredged material sites, especially those considered polluted, previous studies of varying intensities have been conducted. For some others, the general areas in which the disposal sites lie have been the subject of investigations sponsored by academia, foundations, other government agencies, and private industry. The importance of consulting these studies prior to establishing the sampling plan cannot be overemphasized. Such a literature review will have a direct bearing on evaluation of all other secondary factors and will benefit the site designation and monitoring efforts in two ways. On the one hand, the field efforts may be streamlined when literature-available data are sufficient for EIS preparation. On the other hand, a literature survey may point out particular features of the ecosystem requiring special protection, or peculiarities in the physical/chemical environment may be such that a more intense or widespread sampling plan is required.

Configuration

When a site is symmetrical about two or more axes, adequate spatial coverage within the site boundaries can be provided with the basic number of within-site stations for that particular type of site regardless of the current direction. However, as seen in Figure 14, asymmetrical sites are often encountered. In cases where orientation of the recommended sampling axis (upstream/within/downstream) does not correspond

well with the axis of site symmetry, additional sites may be required within the site to provide adequate spatial coverage and to ensure that the point of most probable impact within the site is sampled.

Orientation

Valid comparisons of conditions inside and outside the disposal site require that sampling stations upstream, within, and downstream of the site be aligned along the axis of net current flow (see Figure 15). This should be the primary concern in determining the line along which sampling is to be carried out. However, other factors such as dumping center and depth relief at the site may require deviation from this generalized optimum, in order that other more significant errors in interpretation of results be avoided.

Dumping Center

In most instances the geographic center of the site will not correspond to the area of greatest accumulation of dredged material on the bottom. Unless a specific release point is prescribed in the permit, the dumping center is likely to be near the site boundary more or less on a transit line from the point of origin to the site, i.e., the shortest hauling distance to get within the site. In areas where side casting predominates, the greatest amounts of material will be deposited more uniformly along the boundary of the site nearest and paralleling the channel being dredged. In any instance, a gross bathymetric survey should indicate the general area of greatest accumulation. The purpose in this consideration is that at least one of the sampling stations should be located in the dumping center. Defining the dumping center, one should consider not only the past practice, but more emphasis should be placed on present activity and intended practice in the future.

Depth Relief

At some of the larger and/or deeper disposal sites, considerable differences in depth may exist at various areas within and certainly adjacent to the site. These areas of distinctly differing depths can be expected to support quite different benthic assemblages without regard to any external influences, i.e., dumping. Thus, when defining the sampling transect, based primarily upon the aforementioned factors, one must caution against comparing biota in the upstream, within, and downstream areas when different biotopes are expected to be encountered based on depth considerations alone.

In such cases of significant depth gradients within or around the site, several options are possible. If the currents prevail perpendicular to the depth gradient, or if there is not strong evidence to suggest current flow parallel with the depth gradient, then the sampling stations can be aligned along a depth isopleth. Or, if other evidence suggests a strong need for alignment of the transect with the depth gradient, then additional stations (2) could be located to the sides of the downstream stations at a depth and sufficiently removed from the extended impact zone to allow comparison of these two stations with the two downstream stations. The important point is that comparisons of the benthic fauna should allow for major differences in composition due to natural determinants, e.g., depth.

Current Velocity

The suggested spacing of stations outside the site boundaries is approximately 0.5 and 1.5 miles from the site boundaries. For those sites where currents are strong enough to spread much of the material, additional stations and greater spacing are recommended for the downstream area in order to better define the limits of impact on the bottom. Some interim sites, as off Mobile Bay, are located where tidal currents are more important than longshore currents. In such cases, the flow of

water will reverse during the tidal cycle. Thus, two sides of the site may be impacted, and sampling stations should be spaced accordingly.

Adjacent Amenities

Of major concern is the movement of materials or contaminants toward estuaries, beaches, marine sanctuaries, geographically limited fisheries, or critical areas. Thus, for disposal sites in close proximity to these kinds of features, the sampling plan must consider this possible movement of materials. If these amenities lie in the direction of the sampling transect as determined for that particular disposal site, then the basic upstream or downstream stations are sufficient to document the movement or lack of movement toward these amenities. However, if the amenities are more or less in a direction perpendicular to the sampling axis, then a station (or stations, depending on the proximity) should be located just outside of the site boundary in a line with the amenity to be protected (see Figure 16). If it appears desirable to add sampling stations in the presence of two or more amenities, this should be done.

Proximity to Adjacent Sites

Section 228.4(e)(1)(ii) allows for preparation of an impact assessment of several sites within a geographic area if sufficient data are available in the literature or are gained from a preliminary sampling as to indicate a generic similarity among the sites.

In those instances where several sites are in close proximity (e.g., the Calcasieu or Sabine-Neches sites), the sampling plan can be consolidated to sample all sites collectively. Through this consolidation the number of sampling stations for all sites will be less than the total stations for all sites sampled individually.

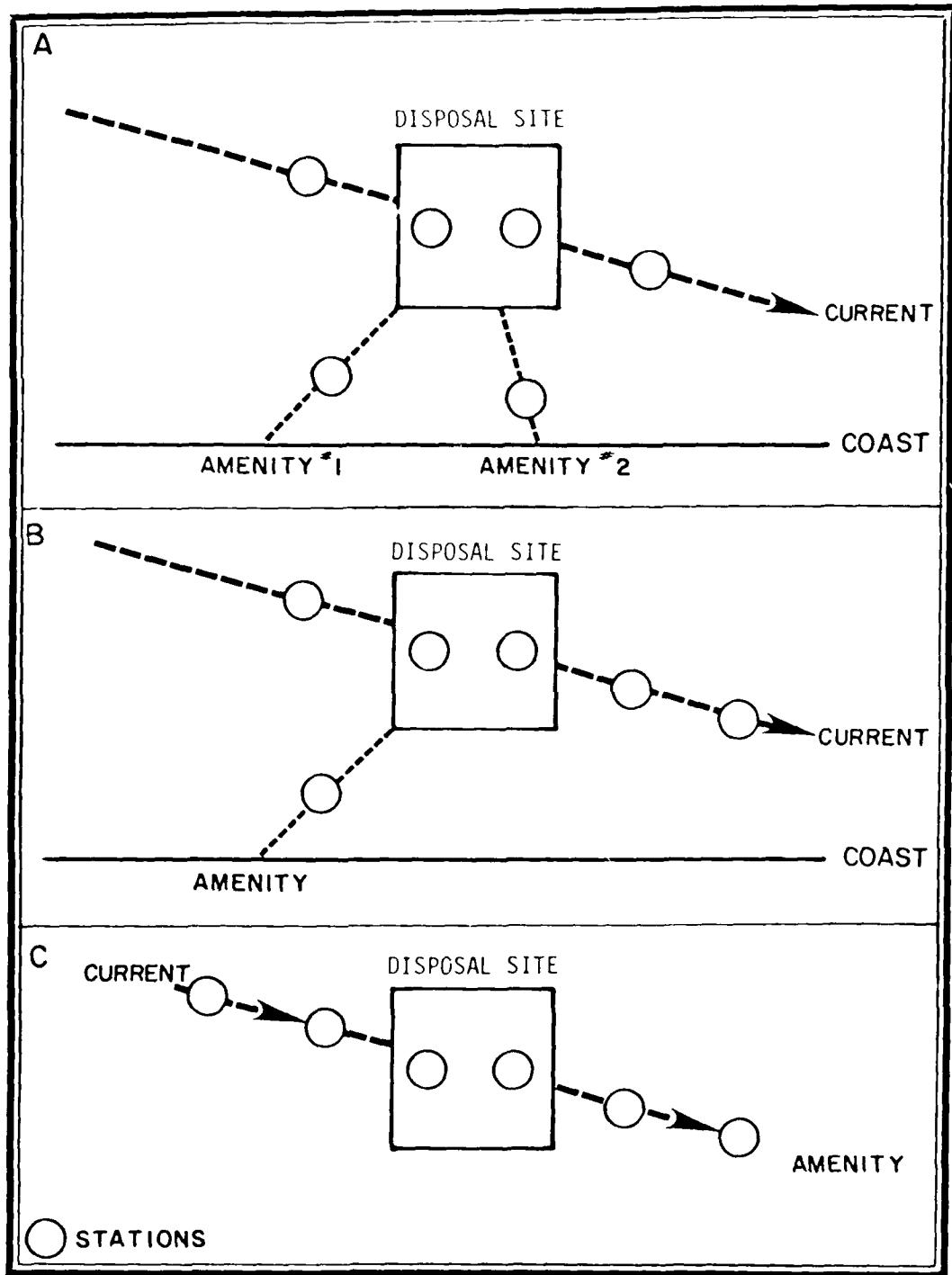


Figure 16. Placement of sampling stations on a typical dredged material disposal site when there are (A) two critical areas at right angles to current, (B) one critical area, and (C) one critical area or amenity downstream of the site.

The basic sampling plan will have to be developed on a specific case basis, and all of the aforementioned secondary factors certainly apply. However, in developing the basic strategy to which additions or modifications can be made, the group of sites should be considered as one site whose area equals the sum of the component sites. The number of within-site stations will probably need to be increased over the basic requirement for that size site because at least one station and probably two (depending on whether the sites are just proximal or contiguous) will be required in each of the component sites. Designation and location of the upstream/downstream sampling locations for the consolidated site should follow the same rationale and consideration of secondary factors as would be applied to a single site of that size. However, it should be recognized early that several dumping centers would be involved and, hence, consideration may have to be given to the concept of multiple extended impact zones, depending on the current regime and orientation of the sites.

AN EXAMPLE

To demonstrate how a specific sampling plan is developed, the process is applied to an actual disposal site. The disposal site at Tiger Pass, Louisiana, was chosen for this example because it is fairly typical of the disposal sites; it has been investigated somewhat but has not been the object of extensive previous investigation, and these data were readily available at the time of writing of this guide. The search for data on the site was not exhaustive; thus, the sampling program should be considered only as an example of how sampling locations are selected.

The Tiger Pass site is located in shallow water (less than 4 meters) and is of medium area (approximately 1 n mi²). For this combination (Type B) three sampling locations within the site, two stations upstream, and two stations downstream are recommended.

For orientation and modification of the sampling plan the secondary factors are considered. A New Construction Dredging Ocean Dumping Assessment (1977) for the Mississippi River Outlets near Venice served as the primary historical data base. Nine sampling stations in and around the disposal site showed no anomalous patterns with respect to sediment texture or contaminants. The most common type of dredging and disposal is by pipeline, thus the dredged material most likely will be fairly evenly deposited over the site with little or no clumping or mounding possible.

The site is rectangular, approximately 0.5 n mi wide by about 2 n mi long, with the long axis more or less perpendicular to the shoreline. With three sampling stations spaced just less than 1 n mi apart within the site, coverage should be adequate.

Nearshore currents in the vicinity of the site parallel the shoreline, i.e., roughly from north to south. Although there is evidence of frequent current reversals (south to north) with season and surface winds, the predominant flow is thought to be to the south. Thus the upstream/downstream axis is perpendicular to the major axis of the site. Because of the relative narrowness of the site, additional sampling stations within the site and along the direction of current flow are unnecessary. Therefore, to this point in consideration of the secondary factors, the sampling program consists of two stations to the north of the middle of the site, two stations to the south of the site, and three stations within the site (the latter oriented perpendicular to the axis connecting the outside sites). This orientation and spacing of stations is illustrated in Figure 17. Care should be taken in placing these stations to the north of the site to avoid sampling in the channel as this area, having been dredged, would likely have a much different benthic faunal composition than those areas unaffected by dredging.

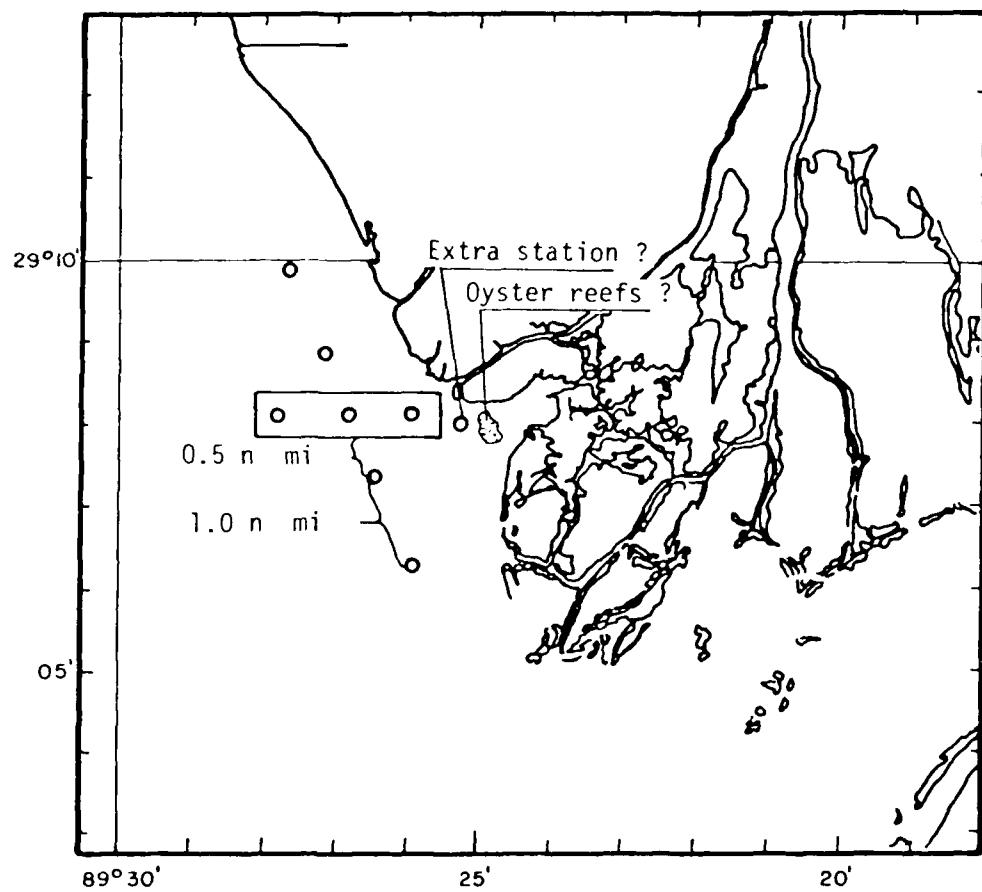


Figure 17. Suggested sampling plan at a Type B dredged material disposal site (Tiger Pass, Louisiana)

Considering the dumping center, the easternmost within-site station would likely suffice if dredged material were barged from Tiger Pass. However, since most is disposed of by pipeline, a fairly uniform dispersal in the site is more likely. Hence, a dumping center is a rather unimportant consideration here.

Depths in and surrounding the site are not likely to account for any faunal zonation which would affect the suggested sampling plan. Thus it, too, is a minor concern in this instance. Low current velocity and shallow depths are such that additional downstream stations would not be necessary.

Oyster reefs exist near the mouth of Tiger Pass, covering approximately 260 acres. The exact location of these reefs was not shown in the data available for this example. Oyster reefs are the type of amenity which would require special consideration. Thus an additional sampling station outside the disposal site, located between the disposal site and the reefs, is suggested after the precise location of the oyster reefs is confirmed.

VI. IMPLEMENTATION OF THE SAMPLING PROGRAM

INTRODUCTION

In any ocean survey, there are certain requirements that must be met in order to ensure a successful survey. Seven major items stand out as essential: (a) adequate vessel, (b) presurvey plan, (c) experienced cruise leader and aides, (d) complete documentation, (e) correct sampling equipment and its proper use, (f) accurate labeling, and (g) proper sample collection and preservation. These cannot be rated in any order of importance since a deficiency in any one of them will probably result in the survey being unsuccessful. Unsuccessful in this context may mean anything from inadequate site coverage, an unusable sample, to no sample collection. Adherence to the above items does not guarantee successful sampling; however, it will greatly increase the probability of success. With the exception of (c) the items listed above will be addressed in more detail in the remainder of this chapter. (A detailed "Chief Scientist's Guide for At-Sea Operations" is found in Appendix A.) Approximate survey time and cost requirements are discussed in Appendix B. Appendix C presents a partial list of survey items and manufacturers.

ADEQUATE VESSEL

SIZE AND DESIGN REQUIREMENTS

The vessel must be capable of operating effectively at the site. It must be remembered that the depths of the 130 disposal sites under consideration in this study range from less than 2 m to over 2000 m: eighty percent of the sites are located in waters less than 40 m deep. In practice, vessel selection will be controlled mainly by the depth; thus the choice will most often be a compromise between the desirable and the feasible. A blue-water oceanographic ship may be required for surveying deeper sites; however, they are generally deep drafted and cannot operate in very shallow water. The size of the vessel is also dependent upon the anticipated sea state at the site. Generally, it

is not possible to sample effectively or safely with a small vessel (less than 80 ft) in seas greater than 4-5 feet unless the vessel is specially designed to meet such conditions.

In addition to meeting size requirements, the vessel must be properly equipped to handle the sampling equipment and the samples. For the purposes of this section of the report, it is assumed that the following kinds of equipment will be used: box corer or bottom grab, benthic trawl, and water samplers.

ELECTRONIC GEAR REQUIREMENTS

Laboratory Equipment

The roll of the ship applies unequal stresses on the ship's electrical generator thus producing a fluctuating electrical current. In general, most electronic gear designed for land-based laboratory use will not function properly unless this electrical current is precisely regulated (both cycles per second and voltage). If the vessel's electricity is not precisely regulated, then sensitive electronic equipment must be battery operated. It may be possible to operate an electronic instrument that is not specifically designed for battery operation by plugging it into an inverter (12 volt DC to 120 AC) which takes its power from a 12-volt lead-acid battery. The battery can be recharged when the electronic equipment is not in use. It is emphasized that the inverter must be tested with every piece of equipment that it is to be used with since off-the-shelf inverters produce a square wave and may not operate some pieces of equipment.

Echo Sounder

Depths should be measured with a graphically recording echo sounder. An echo sounder is a device for measuring the time interval between the emission of a sound signal from a transducer and the returning

echo from the seabed. The instrument then converts time to depth using a constant for speed of sound in water. These devices are commonly called fathometers or precision depth recorders (the latter term usually denotes an instrument having greater precision). The accuracy of the instrument is dependent on a constant speed of movement of the recording stylus and the accuracy of its calibration for the speed of sound in water. Since the speed of sound in seawater varies with temperature, salinity, and pressure, a correction should be applied, especially in deep water, to the depth read on the sounder. The correction may be as much as $\pm 2\%$, and this is certainly unnerving to a winch operator who hits bottom with a sampling device before or after he thinks he should have. (For correction factors see U.S. Naval Oceanographic Office 1966.)

Navigational Aids

Position fixing should have the accuracy of LORAN C or better. It is important to determine accurately the positions at which samples are taken as this will enable comparable samples to be taken at a later date if required. Since repeatability of sample location is the criterion, the bridge and chief scientist's log should express positions initially in terms of, for example, LORAN C coordinates. For any published reports and the EA, however, position data should be converted to latitude and longitude.

ANCHORING REQUIREMENTS

The vessel should be anchored at each station where the box corer or grab is used. This ensures that the ship stays in about the same location for replicate sampling. The chances of a successful sampling by the box corer or grab are greatly increased if the devices are perpendicular to the bottom when they strike and when they are retrieved. Fore and aft anchoring is recommended for deck readout current meters.

The amount of anchor line needed depends upon the vessel, depth, type of anchor, bottom sediment, wind current, and wave action. With the proper weight of Danforth[®] anchor, however, a scope of 4 or 5 to 1 should be sufficient in depths to 40 m (80% of the sites). Less scope and a different anchoring system, perhaps utilizing the dredging winch, can be used if anchoring is attempted in deeper depths.

BENTHIC SAMPLING REQUIREMENTS

Box Corer or Benthic Grab

For the box corer or grab the vessel must be equipped with a davit (boom or A-frame) that will extend outboard for sampler clearance. Normally, the height of the davit should be sufficient so that the gear can be swung in and out manually. This in-out action can also be achieved using a hydraulically controlled davit. In the area where the box corer or grab is to be deployed, it is advisable for safety of operation to have a removable guard rail in order that the devices may be kept as close to the deck as possible during launch and retrieval.

In addition to a davit, a power hoist equipped with a line accumulator is required. In depths less than 40 meters a powered capstan and double-braided nylon line may be the best choice (double-braided lines are preferable to three-stranded lines as they do not twist under strain). The capstan-nylon line combination affords the positive, quick, and controllable response needed for safe operation. Also, the nylon line adds to the shock absorbance capacity of the line accumulator system. For ease of hand-hauling, the minimum line diameter is one-half inch (breaking strength of around 7000 lbs). If wire rope is to be used, the winch must have a positive, quick, and controllable response system such as that given by a hydraulic type. Whatever retrieval system is used, a line accumulator is required.

Trawl

If trawling is to be done at the site, the basic shipboard requirements are about the same as for box coring, i.e., a winch and A-frame (davit or boom). If not already secured for towing, the A-frame must be forward-stayed. In addition the winch need not be the hydraulic type. Under normal towing speeds (~2 knots) a scope of 3 to 1 (wire to depth) will usually suffice in depths to around 100 m; therefore, the winch should be equipped with a minimum of three times the depth plus an additional 100 m. The 100 m will take care of the amount needed to go from the winch through the A-frame, trail back to the water, and the wraps which must remain on the winch drum. Generally, in deeper depths a smaller scope of wire can be used. Other trawling requirements would be: (1) a line accumulator, (2) a metering device for determining amount of wire out, and (3) a powered capstan which is sometimes needed to bring aboard a heavy sample.

Specialized Equipment

In areas where trawling is not possible other sampling devices such as traps, bottom cameras, and television have been recommended. The use of traps should pose no problems if the vessel is equipped for box coring and trawling since a winch (and/or capstan) and davit are all that are required.

Use of bottom cameras or television may require specialized electronic equipment to determine their height above the bottom. Additionally, specialized winches may be required, especially in deeper water, if a conductive cable is used. It is imperative, therefore, that the contractor detail any of his special needs to the person in charge of vessel procurement and outfitting.

WATER SAMPLING REQUIREMENTS

Sampling of the water column will be accomplished by (1) taking discrete samples for on-board or laboratory analysis, and (2) measuring the parameters *in situ*. Discrete samples can be taken using a hand-held line in shallow water or by using a winch and davit in deeper water. The same winch-davit combination used for box coring can be used for water sampling provided that the wire is not too large for messengers or sample bottle attachment. Depending on their weight, *in situ* devices, such as the STD, transmissometer, and other types of probes, can be hand lowered in shallow water; however, heavy probes or deeper water require the use of a special winch which can accommodate conductive cable.

LABORATORY AND STORAGE SPACE REQUIREMENTS

The survey plan should include vessel specifications for laboratory and storage space. For example, if the survey vessel returns to port each night, the needs for laboratory and storage space may be minimal; however, if the vessel is to be away from port for a number of survey days, then laboratory and storage space may become quite significant. Even on day cruises there should be at a minimum a desk for the chief scientist and laboratory bench space of 20-30 square feet for sample preparation and shipboard analyses.

There also must be provisions for refrigeration and freezing. Some samples must be refrigerated while others require initial quick freezing. Samples requiring refrigeration can be placed and stored in a conventional refrigerator or they can be placed on wet ice and later stored in a refrigerator. For quick freezing, a forced air freezer, dry ice, or liquid nitrogen can be used; once the samples are frozen, they can be stored in a conventional freezer. The amount of refrigerator and freezer space is dependent upon the number of samples to be stored before land facilities can be utilized.

PRESURVEY PLAN

Essentially, a presurvey plan is a detailed account of what is to be accomplished and how and where it is to be done. The main purposes of the plan are to ensure that (1) samples are taken from the proper location; (2) the chief scientist knows the full extent of the survey; (3) there are expert and trained backup personnel for each operation; (4) all necessary equipment, supplies, and backup are available; (5) all samples arrive at designated laboratories in the proper state of preservation in a timely manner; and (6) all data are tracked and processed.

The plan must contain locations for all primary sampling stations along with a detailed account of the sampling to be accomplished at each station. The plan should explain the intent of the survey so that if the need arises the chief scientist may alter the sampling procedures. It is advisable that an alternate sample station be assigned for each primary station. For example, depth at a primary station may be four feet instead of the 10 feet as shown on bathymetric charts and thus the station is too shallow to be sampled. There are many other reasons why a primary site may not be samplable; thus, the plan should indicate an alternate area or at least in which direction an alternate site should be located in relation to the primary site.

It is essential that there be expert and qualified backup personnel for each operation. The plan should list the cruise and onshore personnel along with their primary and secondary responsibilities. The completion of this task should eliminate any unfilled responsibilities as well as ensure that necessary equipment and supplies are available when needed.

The plan shall also contain all logistical operations. This shall include: transportation to and from the vessel for personnel, equipment,

and supplies; scheduled port calls; sample storage; and sample routine to the respective laboratories.

DOCUMENTATION

Documentation for the survey should include the following: bridge log, meteorology log, chief scientist's log, records and notes by aides, results of shipboard analyses, sample inventory logs, and summary cruise report. Time should be kept on the basis of a 24-hour clock and in local time. Any changes in time zones should also be clearly noted on each log.

The bridge log is maintained by the ship's officer or aide. All events pertaining to the ship and sampling operation should be identified by date, time, position (using navigational aid coordinates and calculated latitude and longitude), instrument used to determine position, and an estimation of position accuracy. It may be advantageous to have the bridge watch keep the meteorological log. The meteorological log should be kept on a printed form having the following minimum entries: date, time, location, weather condition, wind (speed and direction), air temperature, and sea state (height and direction). Meteorological observations should be taken at 3-hour intervals or less. Sudden changes, if they occur within the predetermined observation interval, should also be recorded.

The chief scientist's log shall include as a minimum the time of departure from and return to dock; and time, depth, location, and type of gear for each sample collected (time, depth, and location at beginning and end of sampling if not on anchor). Any deviations from normal procedures should be noted.

Other records to be kept by the scientific party should include results of shipboard analyses and notes on samples and sample collection. Considering the high cost of operating ships for site surveys, an

effort should be made to gather observational data so long as it does not extend the time required for the basic survey. Therefore, special attention should be given to recording sightings of birds, mammals, and turtles during the survey. These components of the fauna, with some being designated as threatened or endangered, are of considerable political as well as environmental importance. Such site specific data should be used in the description of the environment in an ensuing EIS or monitoring report. Information to be recorded shall include identification or description, number, time, date, location, and estimated direction of travel. If the chief scientist's log is open to all personnel, then many of the individual notes can be recorded into it. The above additional observations will enhance the value of environmental assessments to diverse users at little or no additional cost.

It is preferable that the sample inventory log be maintained throughout the survey; however, it can be prepared during demobilization. If more than one site is visited, it is suggested that the inventory be completed by the end of each site survey. The sample inventory log should be in form format and shall identify all samples for laboratory analysis. Information to be reported for each sample shall include as a minimum: label code number, location (or station number), analysis to be performed, depth, date of collection, and special remarks pertinent to analysis or interpretation of results.

The summary cruise report shall include a list of participants; a map of the station locations; a list of cruise objectives versus data obtained; and a combination and interpretation on a chronological basis of all logs and notes taken during the survey. Data forms need not be included in the text. However, they, along with originals of all logs, etc., should be appended to the report. As soon as possible, copies of all cruise information should be made and stored in separate locations.

SAMPLING EQUIPMENT AND ITS USE

BOX CORER

It is suggested that sediment samples be collected with a box corer of the type shown in Figure 18. If other devices are used, they should fulfill the following requirements: (1) obtain a quantitative sample, (2) obtain a relatively undisturbed sample, (3) provide sufficient volumes of sediment for required analyses, and (4) be as noncontaminating as possible.

Ideally, the box corer should be used with the ship on anchor. In deeper water, or when it is impractical to anchor, the following methods can be used to return to the station for replicate sampling: (1) return to the original navigational aid coordinate (this is facilitated if an automatic track plotter is available), or (2) anchor one or more marker buoys and return to the original position relative to the marker buoys.

The lowering technique used for sample collection depends upon the amount of weight attached to the corer and the hardness of the sediment. Weights can be added to the box corer shown in Figure 18. It is imperative to collect an undisturbed sediment sample. When retrieved, the box corer should have at least one or two inches of water overlying the collected sediment. If penetration is too deep, the sediment will be extruded out the top of the corer (remove weight or drop slowly), whereas too shallow a penetration will not collect enough sediment to form a watertight seal (add weight). As soon as bottom is reached and the line is slackened, hauling in should begin immediately. Any delay on the bottom may increase the wire angle causing the corer to be pulled out obliquely. It is important to haul in line very slowly until the corer has left the bottom because (1) the closing of the corer is completed as hauling begins and a sudden jerk may raise the corer before closing, and (2) the corer may be deep in the sediment and a sudden jerk may damage the corer or break the line. Upon

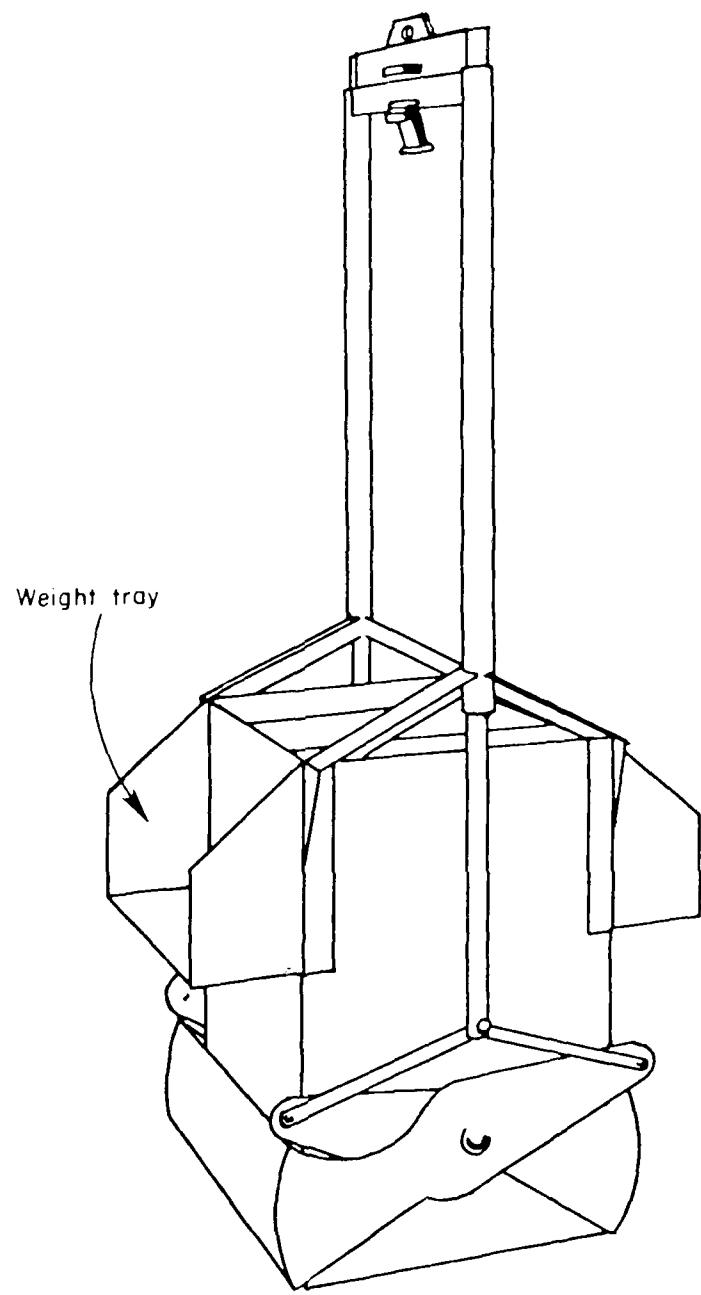


Figure 18. Box corer (Grav-O'Hara modification of the J & O box corer). For deeper penetration in hard sediments, weights can be attached to the shelves located on opposite sides.

retrieval, the corer should be placed in a suitable container, i.e., a short wooden box with handles and a nonskid bottom. After the subsampling tubes for granulometry and meiotauma, if this is desired, are in place, the box corer should be tilted slightly and the water above the sediment gently siphoned off. This is necessary if meiofauna are being sampled because some species live in the surficial flocculent layer. Subsampling for the remaining parameters should be done after the overlying water has been removed. For macrofaunal sampling, the overlying water should be siphoned off before the box corer is emptied into the box.

In the event that a successful sample is not obtained in three attempts and weights have been added or taken off as necessary, an alternative sampling device may be substituted or a secondary station may be visited. The chief scientist's log should contain the reasons for the sampling failures and the selection of alternative sampling devices or for visiting a secondary station.

BEAM TRAWL

A beam trawl (Figure 19) is the recommended gear for sampling the macroepifauna. The beam trawl is preferred over the otter trawl since the mouth of the beam trawl net is held at a constant opening. The mouth of the net is held open by a steel beam of 3 meters length with steel runners on each end. A standard net is made of 1.5-inch stretch mesh and beginning at the throat it has an inner liner of 0.5-inch stretch mesh. The trawl is attached to the towing wire by a short (compared with the otter trawl) three-point bridle.

The launching of the trawl may be from the stern or side of the ship. If the towing is to be from the side of the ship, the wind must be blowing onto that side during launch and retrieval so that the ship is blown away from the net in order to avoid entanglement with the ship's propeller or rudder. If the net is to be launched from the port side, for example, it is sometimes advantageous to have the ship in a shallow

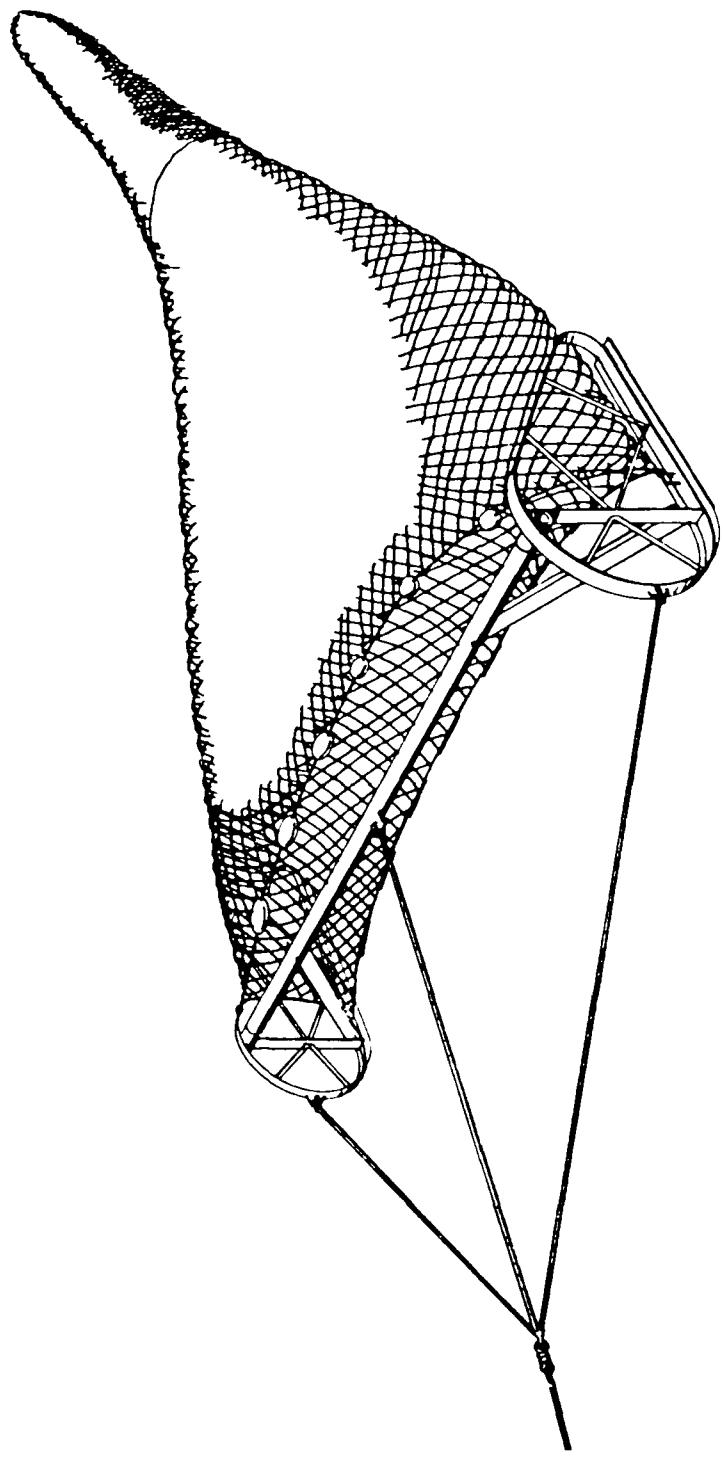


Figure 19. Beam trawl. The beam holds the skids and thus the mouth of the net at a constant opening. Extra strength can be provided using an angle iron brace from the beam to the bottom of the skids.

port turn. When stern launching the trawl, one should be sure that the net is shot far enough aft to be out of the back wash of the propellers. It may be necessary to momentarily stop the engines (but not the forward motion) until the net is clear of the stern. After the net is clear from either stern or side launching and after it is sure that the trawl is upright and untangled, the wire should be paid out under slight tension. In depths to about 30 m the amount of wire needed will be about three or four times the depth plus the amount of wire needed from the metering device to the water. Past a depth of 30 m, the wire required may be lessened to about 2.5 times the water depth. When sufficient wire has been paid out, the ship's speed should be adjusted to around 2 knots. A suggested standard towing time is 10 minutes on bottom. In any case, a uniform tow speed and time should be adhered to for a particular area. The ship's position should be recorded for the beginning and end of the 10-minute period. After the net is brought aboard, its contents should be photographed and emptied into a noncontaminating container. A thorough examination of the net is required to make sure all organisms have been removed so that they will not contaminate the next sample. Finally, the net should be thoroughly washed with site water.

DEVICES FOR IN SITU BIOASSAY OR BIOACCUMULATION - OPTIONAL

There are a variety of ways whereby test organisms may be exposed to DM in the field and retrieved after a period of exposure. In shallow sites this operation could be accomplished by scuba divers; however, such sites might tend to be characterized by natural turbidity which would certainly hamper diver capability. A more idealistic approach would be the deployment of a caging container of flow-through characteristics loaded with desired organisms from the surface vessel. Examples of such a container would be the Benthic Biotal Ocean Monitor (Pequegnat 1978), Monitoring Platforms (Naval Underwater Systems Center 1979), and specially constructed, weighted cages of one's own specification (these would have to be fabricated from material of a

noncorrosive and uncontaminating nature). The unit should be rigged with an acoustic pinger and subsurface floats to be freed by a mechanical release (either time or acoustic type) at the desired time. The pinger would act as a fail-safe device in the event of malfunction of the release mechanism in that its sound could be used to home in on the submerged array during search and recovery operations.

SALINITY-TEMPERATURE-DEPTH/DISSOLVED OXYGEN (STD/DO) PROBE

For determination of these standard oceanographic water column parameters a Salinity-Temperature-Depth/Dissolved Oxygen (STD/DO) probe system is recommended. Although these probes are generally not as accurate as the reversing thermometer-Niskin bottle method, they are sufficient for the descriptive work recommended herein. The calibrated minimum accuracy of the system should be: temperature $\pm 0.1^{\circ}\text{C}$, salinity $\pm 0.1 \text{ ppt}$, depth $\pm 1\%$ full scale, dissolved oxygen $\pm 0.1 \text{ ppm}$. The instrument should be calibrated according to the manufacturer's instructions and verified in the field. Verification shall be performed on a water sample collected at a depth of 1 meter simultaneously with STD/DO probe measurement. Temperature verification shall be made using a National Bureau of Standards certified thermometer or better. Salinity should be verified with an instrument having an accuracy of at least $\pm 0.01 \text{ ppt}$. Dissolved oxygen shall be analyzed by a method equivalent to or better than Strickland and Parsons (1972).

If a STD/DO probe system is not available or if near bottom cannot be reached with it, then these parameters must be collected using the standard oceanographic technique of reversing thermometers and water bottles and then analyzed as outlined above for verification samples.

TRANSMISSOMETER

To determine water clarity or turbidity of the water column, the use of a transmissometer is recommended. Basically, a transmissometer

consists of a light source and a light detector separated from each other by a known distance referred to as the light path length. The instrument is calibrated so that a reading of 100% light transmission is obtainable in distilled water.

For clear to turbid waters the usual light path length used is 1 m, but for very turbid waters a 0.25-m or 0.1-m light path length is recommended. Some instruments are convertable from one path length to another while others have fixed path lengths. Whichever type is used, the body of the transmissometer must remain rigid since a slight movement may affect the alignment between the light source and the detector.

WATER SAMPLERS

As stated in Chapter V, water samples for trace metals, hydrocarbons, and pesticides are to be collected very near the bottom at all sites and in middepths at some of the sites. Samples may be collected using water sampling bottles or a submersible pump system. Whatever sampling device is used, it must be noncontaminating to the kind of sample collected.

The preferred method for sampling very near the bottom is a sample bottle equipped with a bottom-activated closing mechanism. To be non-contaminating the bottle should be nonmetallic (if used for trace metal sampling), teflon lined, and of the close-open-close type. In addition, all components within about five meters of the bottle should be noncontaminating, i.e., lowering wire, and bottom-activated closing mechanism (the lowering wire and bottom-activated closing mechanism can be polyethylene sheathed; small components can be coated with epoxy). The system must be precleaned before each lowering using a 1:1 hydrochloric acid-distilled water rinse for trace metal sampling and a hexane rinse for hydrocarbon or pesticide sampling. To facilitate sampling in deep water, it is advisable to attach a pinger above the sample bottle and at a known distance above the closing mechanism.

This enables precise location of the closing mechanism relative to the bottom during any point in the lowering process. The use of a pinger enables samples to be taken under conditions when they otherwise could not be obtained.

For shallow depths a submersible pump system may be preferable. Since the system may become contaminated while being lowered to the sampling depth, sampling should not commence until at least a volume equal to 10 times the tubing volume has been pumped through the system.

Whatever sampling system is used, care must be taken that it will not contaminate the sample. For trace metals, the bottle should be nonmetallic, and all components of the sampling system within 5 meters of the bottle should be nonmetallic. For hydrocarbons and pesticides, the bottle should be glass and precleaned with hexane.

CURRENT METER

The ship should be anchored during all measurements using a current meter. In shallow water the ship should be anchored fore and aft, since the ship itself on a single point anchorage could produce up to a 0.2-knot distortion. For near-bottom current measurements in deep water, special equipment may be necessary. A system used by Pequegnat (1972) proved successful in depths over 3000 m.

The current meter should be one which is least affected by up-and-down motions of the ship and has a recording deck readout component. The deck readout component is preferable since one can readily ascertain if the unit is functioning and if or when the ship's action is influencing the meter. To minimize the up-and-down effect on the current meter due to the motion of the ship when anchored fore and aft, the current meter should be deployed from midship.

One must be cognizant of the fact that the directional component of

the current meter is magnetically determined and thereby can be influenced by adjacent metal objects, i.e., ship's steel hull (vessels with wooden or aluminum hulls will produce negligible effects). Additionally, in the vicinity of the ship's hull the current field is distorted; thus, current measurements taken above the draft of the ship are unreliable.

Meteorological observations (wind speed and direction and sea and swell height and direction) shall be taken at the beginning and at the end of the current meter measurements. Additional meteorological observations shall be taken if duration of current meter measurement is greater than one hour or if sudden meteorological changes occur during the current measurement.

Placement of current meter, duration of measurement, and field use of data are outlined in the "Chief Scientist's Guide for At-Sea Operations" (Appendix A). Essentially, however, current measurements are to be taken very near the bottom and at middepths in order to determine the exact placement of sampling stations and to determine the current when a two-layered system is present.

LABELING

Correct sample labeling is one of the more important aspects of any field sampling program. There are many label systems and it would be presumptuous to recommend which is best. Any labeling method, however, should fulfill the following minimum requirements: labeling must be permanent; noncontaminating to the sample; readable from the outside of the container; easily traceable to the chief scientist's log; and recognizable as to location of collection, type of sample, and type of analysis to be performed. It is advisable that the label be a simple code or contain a simple code that is easily traceable to the chief scientist's log so it can be used by laboratories in their analysis report. In addition, if there is anything out of the ordinary that

may affect the laboratory analysis or its interpretation, the sample label should be flagged to draw special attention from laboratory personnel. An explanation of the flag must be contained in the chief scientist's log and be sent to the laboratory along with the sample.

Permanence of the label is a problem. Many permanent inks are not permanent if used in alcohols or other preservatives. Even some India inks will wash off unless they are completely cured on an absorbent type paper. A number two pencil is best for paper labels. If paper is used, it must be 100% rag or there is a good possibility it will disintegrate when wet. If labeling is to be done on plastic, the plastic must be dry and at room temperature and marked with a permanent felt pen. After the ink has dried, the label should be covered and sealed with a clear vinyl waterproof packaging tape that is secured by being placed around the entire container. It must be stressed that whatever type of labeling supplies are used, they must be thoroughly tested for permanence in every type of environment to which they may be subjected. Do not assume that just because it tested waterproof that it will be freezer and thaw proof.

Samples for different kinds of analyses may require different labeling techniques so it is important to plan the labeling technique for each type of sample. The label must not touch a sample on which chemical analyses are to be performed. In this case, the label can be attached to the outside of the container or both container and label can be placed together in a plastic bag. Since the precruise plan will identify the type, number, and general location of samples to be collected, it is advisable to enclose or attach a partially completed label with each sample container prior to the cruise. These can be preprinted.

SAMPLING AND PRESERVATION

WATER COLUMN

Water Column Trace Metals

Two samples are to be collected for trace metal analysis: one for mercury and one for the other trace metals to be analyzed. Sample containers for mercury samples shall be 1-l glass bottles with caps lined with teflon, whereas for the other trace metal samples the containers shall be 1-l linear polyethylene bottles and caps. All containers, lids, and apparatus (except for filters) which contact the sample shall be precleaned before loading on board in the following manner: thoroughly washed with detergent and tap water; rinsed with 1:1 nitric acid, tap water, 1:1 hydrochloric acid, and tap water; and finally rinsed with deionized distilled water (U.S. EPA 1976b). Filters are precleaned in the same manner except they are not washed with detergent.

The sample is collected as previously described then filtered through a 0.4- μm polycarbonate (Nucleopore[®]) filter. Samples shall be placed in their proper container to which has been added 5 ml ultrapure (Ultrex) HCl. All filtering and direct sample handling must be carried out in a clean environment. Samples shall be stored at 4°C.

Water Column High Molecular Weight Hydrocarbons, PCBs, and Chlorinated Pesticides

Two samples should be collected: one for high molecular weight hydrocarbons and one for PCBs and chlorinated pesticides. Sample containers for both of the above shall be 3.8-l glass bottles with caps lined with teflon. All containers, lids, and apparatus which contact the sample shall be thoroughly rinsed with pesticide-grade hexane.

The sample should be collected as previously described and a minimum of 3 l should be placed unfiltered into a 3.8-l bottle to which has been added 300 ml pesticide-grade hexane. Samples should be stored in the dark at ambient temperature.

Water Column Temperature, Salinity, and Dissolved Oxygen

It is recommended that an STD/DO probe be used to profile the water column from the surface to the bottom or to at least 100 m, whichever is the lesser. If the depth of the site is greater than 100 m or beyond the depth capabilities of the STD/DO probe, then a discrete near-bottom sample shall be taken for temperature, salinity, and dissolved oxygen (near-bottom temperature and salinity need not be taken if documentable by recent data). Discrete near-bottom samples shall be collected as described above for high molecular weight hydrocarbons and analyzed as outlined earlier for verification samples. The STD/DO probe shall be calibrated by the manufacturer's instructions or better. Verification samples should be collected and analyzed as described earlier under recommended sampling equipment.

If an STD/DO probe is not used for profiling the water column, then water bottles with reversing thermometers should be used according to instructions equal to or better than those given in U. S. Naval Hydrographic Office Pub. No. 607 (1968). The distance between sampling bottles shall be such that the thermocline and halocline are adequately depicted; therefore, the data should be analyzed immediately and perhaps redone until the depiction is accurate. Near-bottom samples should be collected as described above.

Turbidity

It is recommended that a transmissometer with depth indicator be used to profile the water column from the surface to within 1 m of the bottom or to a depth of 100 m, whichever is the lesser. In addition, a discrete water sample for total suspended solids (TSS) shall be collected in the most turbid portion of the water column as detected during lowering and verified during retrieval of the transmissometer. To ensure that the discrete sample is collected in the most turbid portion of the water column, it is recommended that (1) a water sampling

bottle be attached to the transmissometer cable, or (2) the transmissometer be attached to the water sampling bottle lowering line. If the depth of the site is greater than 100 m and beyond the depth capabilities for the transmissometer, then an additional discrete sample for TSS shall be collected very near the bottom. The additional near-bottom sample should be collected as described in the section on high molecular weight hydrocarbons.

For TSS, a minimum of 1 l shall be drawn from the discrete water sampler. The sample shall be vacuum-filtered (up to 29 inches Hg) through a preweighed, 0.4- μ m polycarbonate (Nucleopore[®]) filter. The volume of sample to be filtered shall be 1 l or the amount required to almost clog the filter, whichever is the greater. After determining and recording the sample volume which was filtered, the inside of the filtering apparatus should be rinsed with about 10 ml of distilled water; then the filter should be vacuumed to dryness (additional distilled water rinses shall be performed at the laboratory). The filter shall then be placed in an individually labeled pillbox, plastic container and stored at ambient temperature and returned to the laboratory.

SEDIMENT

General

A 30-cm by 30-cm box corer should provide ample material so that all samples for the analyses can be subsampled from the sediment collected by a single sampling. Subsamples shall be taken while the sediment is still in the box corer. During subsampling, in order to prevent migration of meiofaunal organisms and prevent chemical contamination, it is important that the subsamples be taken in the following order: meiofauna and granulometry, trace metals, PCBs and chlorinated pesticides, high molecular weight hydrocarbons, oil and grease, and total organic carbon (TOC).

It is imperative that the box corer sample chosen for sediment analysis be as undisturbed as possible. Since a minimum of six box corer samples will be taken at each station (one for sediment analysis and five for macrofauna), the one chosen for sediment analysis should be the first sample which is retrieved in an undisturbed state. Proper use of the box corer has been given in a previous section of this manual (page 139).

Meiofauna and Granulometry

Two granulometry samples and two optional meiofaunal samples shall be taken from the box corer using precleaned, 3.45-cm i.d. Plexiglas[®] coring tubes. (The tubes shall be cleaned in the laboratory by soaking them in 1 N HCl. In the field the tubes shall be washed with fresh water then rinsed with 0.1 N HCl after each use.) With the water still in the box corer, the tubes should be pushed into the top 10-20 cm of the sediment and then rubber stoppers (No. 6 or 7) placed in the tops of the coring tubes. The overlying water in the box corer should then be siphoned off. After all other samples have been taken, an additional stopper should be placed in the bottom of each tube, then the tubes slowly drawn from the sediment. The stoppered Plexiglas[®] tube should now contain the sediment sample plus the overlying water. The overlying water should be carefully decanted onto a 63-μ sieve. Material retained by the sieve should be backwashed into the jar in which the meiofauna sample is to be placed.

For the meiofaunal sample the top 5 cm of the sample should then be extruded (15 cm if sediment is sand), using a plunger placed in the bottom of the tube, directly into a sample jar (glass or plastic). The organisms should then be immediately narcotized using an isotonic solution of magnesium chloride (70 g MgCl₂/L is isotonic with 3‰ ppt seawater). The sample should be covered with the isotonic solution and shaken vigorously for a few seconds. After the sample has set in a cool place (not the sun) for about 30 minutes, the liquid should be

decanted through a small 63- μ sieve. The sieve should then be backwashed into the sample jar and the jar filled with a 5% buffered formalin solution. The jar should then be shaken to achieve a uniform mixture of the preservative. The samples can be stored at ambient temperature (do not freeze).

For the granulometry, a 10-cm sample should be extruded from the tube into the labeled container (glass or plastic jar or plastic bag) in which the sieved material was placed. The sample shall be stored at ambient temperature.

Sediment Trace Metals

Two trace metal samples should be taken: one for mercury and one for the remainder of the trace metals. Each sample shall be subsampled from the center region of the box corer so that metal contamination from the box corer itself will be negligible. Each sample shall consist of a minimum of 40 g and shall be taken with an acid-cleaned plastic coring device preferably similar to a piston corer. (An acid-cleaned, 50-cc plastic disposable syringe with the end cut off has been used quite successfully. It is preferable, however, to replace the rubber-ended plunger with one made of teflon.) Each sample should be extruded directly into a separate, precleaned (see previous section for cleaning instructions) container such as a 40-dram plastic vial with cap. The cap should be secured to the vial with tape; then the sample and label should be placed in a plastic bag. Samples should be frozen and delivered to the laboratory in a frozen state.

Sediment PCBs and Chlorinated Pesticides

For PCB and chlorinated pesticide analyses, one sample shall be obtained by subsampling from the box corer. A minimum of 100 g of sediment, or about a cup, shall be taken with a noncontaminating scoop, spoon, or corer which has been precleaned with pesticide-grade hexane. The

sample shall be placed in a precleaned, freezer-type glass jar that has a lid lined with teflon or aluminum (do not fill the jar over three-fourths full). The sample shall be labeled on the outside of the jar, frozen, and delivered to the laboratory in a frozen state.

Sediment High Molecular Weight Hydrocarbons

The sample for high molecular weight hydrocarbon analysis shall be obtained by subsampling from the box corer. A minimum of 50 g of sediment, but preferably one half of a pint jar, shall be taken with a noncontaminating scoop, spoon, or corer which has been precleaned with pesticide-grade hexane. The sample shall be placed in a precleaned, freezer-type glass jar that has a lid lined with teflon or aluminum (do not fill the jar over three-fourths full). The sample shall be labeled on the outside of the jar, frozen, and delivered to the laboratory in a frozen state.

Sediment Oil and Grease

The sample for oil and grease analysis shall be obtained by subsampling from the box corer. A minimum of 100 g, but preferably one half of a pint jar, shall be taken with a noncontaminating scoop, spoon, or corer which has been precleaned with pesticide-grade hexane. The sample shall be placed in a precleaned, freezer-type glass jar that has a lid lined with teflon or aluminum (do not fill the jar over three-fourths full). The sample shall be labeled on the outside of the jar, frozen, and delivered to the laboratory in a frozen state.

Sediment Total Organic Carbon (TOC)

The sample for TOC shall be obtained by subsampling from the box corer. A minimum of 25 g shall be taken with a noncontaminating scoop, spoon, or corer which has been precleaned with pesticide-grade hexane. The sample shall be placed in a precleaned, freezer-type

glass jar that has a lid lined with teflon or aluminum (do not fill jar over three-fourths full). The sample shall be labeled on the outside of the jar, frozen, and delivered to the laboratory in a frozen state.

BENTHOS - MACROINFAUNA

Five replicates should be taken with a box corer at each station chosen for macrofaunal sampling. Additionally, two granulometry subsamples shall be taken from first and second macrofaunal box cores. When the box corer is retrieved after a successful lowering, it should be placed in a wooden box. After siphoning off the water, the contents of the box corer should be carefully emptied into the wooden box (most sediment cores will retain their integrity long enough to take the sample; however, if the sediment is incohesive, the sample must be taken directly out of the box corer). Using a large scoop or spatula the top 15 cm of the core should be removed and placed in a sample container; the top 15 cm of a 30-cm by 30-cm box corer will fit nicely into a five-gallon bucket. The rest should be disposed overboard. The sample container should be labeled on the outside and inside, then fitted with a lid. Samples shall be processed (sieved and preserved) within 24 hours of collection. If they are not processed immediately, they should be stored in a shaded area. On vessels which return to port each night, it may be advantageous to process the sample onshore.

Macrofaunal organisms are defined herein as those organisms which are retained on a 0.5-mm sieve. In practice it is suggested that the sample be washed on nested sieves, i.e., 5 mm then 0.5 mm (within limits the mesh size of the larger sieve is not too important). The larger upper sieve will screen out many of the larger fractions; however, more importantly it protects the integrity of the 0.5-mm sieve. The sample shall be placed on the top sieve and washed with a gentle spray of freshwater or saltwater. It should be remembered that most macrofaunal organisms have extremely fragile bodies that damage

easily when handled extensively. When a specimen is observed in a sample during sieving, it should be removed immediately with forceps and placed in a labeled container. After the sample is completely washed, it along with a label shall be placed in a glass or plastic jar which has a lid lined with noncorrosive material. The sample shall then be preserved with a volume of 5% buffered formalin equal to at least the volume of the sample. For ease of identification a label or code should also be affixed to the outside of the sample container. The sample can now be stored and transferred to the laboratory at ambient temperatures (do not freeze).

BENTHOS - MACROEPIFAUNA

General

If possible, macroepifaunal samples shall be collected with a beam trawl. In areas where trawling cannot be done, macroepifaunal samples should be collected using traps. Crab or lobster traps should suffice. When traps are used, it is recommended that local fishermen be consulted on their design and use. Samples collected by either method shall be treated the same.

The following types of analyses shall be performed on the macroepifaunal sample: a simple determination of biomass; identification and enumeration; trace metals; PCBs and chlorinated pesticides; and high molecular weight hydrocarbons. In order to accomplish the above, two samples at each station are recommended.

All organisms which are returned to the laboratory for chemical analysis must be identified to genus or species and enumerated aboard ship or at the laboratory prior to chemical analysis. It is imperative that these data be consolidated with those of the identification-enumeration portion of the sample so that the entire sample can be accounted for.

Biomass

The determination of wet weight biomass shall be done immediately after the sample is taken from the trawl. It is recommended that a pull type, spring scale balance having a minimum accuracy of 1% of full scale be used for the weighing of the organisms. In order to accommodate small and large samples, it is advisable that at least two balances of different capacity be available, e.g., 2 kg and 10 kg. The balances shall be calibrated in the laboratory prior to the survey and verified aboard ship before biomass weighings. A single point verification (minimum) shall be performed using a known weight of approximately one half the balance capacity.

The organisms shall be placed in a previously tared, noncontaminating mesh bag (e.g. nylon), allowed to drain for 1 minute, and then weighed using the hand-held balance. The balance serial number, verification weighing, and biomass determination shall be entered into the chief scientist's log.

Tissue Samples

Tissue Trace Metals. First choice for selection of organisms for tissue analysis shall be fish or shellfish which are directly consumable by man; preferably, both a fish and a shellfish should be selected for analysis. For trace metal analysis, 30-g wet weight edible tissue is required. If this weight cannot be obtained by using a single organism, then enough individuals of the same species can be pooled.

Organisms for analysis shall be removed from the trawl sample with non-metallic forceps or plastic gloves and each 30-g sample shall be placed in a separate plastic bag. Then the bag and a label shall be placed into another plastic bag. Samples shall be quick frozen and delivered to the laboratory in a frozen state.

Tissue PCBs and Chlorinated Pesticides. First choice for selection of organisms for tissue analysis shall be fish or shellfish which are directly consumable by man; preferably, both a fish and a shellfish should be selected for analysis. For PCBs and chlorinated pesticide analyses, 100-g wet weight edible tissue is required. If this weight cannot be obtained by using a single organism, then enough individuals of the same species can be pooled.

Organisms for analysis shall be removed from the trawl sample with hexane-cleaned stainless steel forceps. Each 100-g sample shall be wrapped airtight in hexane-cleaned extra heavy duty aluminum foil. Samples shall be labeled on the outside, quick frozen, and delivered to the laboratory in a frozen state.

Tissue High Molecular Weight Hydrocarbons. The shipboard procedure for these tissue sample analyses is the same as for PCBs and chlorinated pesticides except that a 50-g sample is required instead of a 100-g sample.

Identification and Enumeration

The remainder of the trawl sample after removal of organisms for chemical analysis shall be placed in a noncorrosive 1- to 5-gallon container and preserved with 5% buffered formalin. The volume of preservative shall be equal to or greater than the volume of the organisms. In addition, the thoracic cavity of fish longer than about 10 cm should also be injected with 5% buffered formalin. The label for this sample shall note whether it is the entire trawl sample or if only a part as a result of samples taken for chemical analyses. After preserving, the sample can be stored and returned to the laboratory at ambient temperature.

IN SITU BIOASSAY OR BIOACCUMULATION - OPTIONAL

As mentioned earlier in this chapter (see "Devices for In Situ Bioassay or Bioaccumulation" page 143), cages are available that will hold laboratory organisms and/or capture indigenous organisms. Laboratory organisms are those which have been captured and allowed to depurate. The cage device is loaded with laboratory organisms and deployed at the location chosen for the test. The cages with their organisms should remain in situ for at least four days (96 hours). After retrieval, the following laboratory analyses can be performed on the captured and/or laboratory organisms: identification and enumeration, trace metals, PCBs and chlorinated pesticides, high molecular weight hydrocarbons, enzymes, and adenylate energy charge. Except for enzymes and adenylate energy charge, organisms shall be handled, packaged, and preserved as outlined for their specific analysis in the preceding "Macroepifauna" section. Organisms for enzyme and adenylate energy charge analyses require special shipboard procedures.

Enzymes

Within one hour of collection, livers of laboratory fish (i.e., Fundulus similis, F. grandis) should be excised, pooled in groups of five, placed in 7-dram plastic vials, and quick frozen in a solution of 20% glycerol (v/v) in 50 mM morpholinopropane sulfonic acid (MOPS) buffer (pH to 7.6 with NaOH). The tissue should be stored frozen and delivered to the laboratory frozen. If the fish are also to be used for trace metal analysis, they should be dissected in a clean environment using a stainless steel bladed scalpel precleaned with 0.1 N HCl and rinsed with distilled water. Specimens for trace metal analysis should be packaged, stored, and transferred to the laboratory as outlined under the "Macroepifauna" section.

Adenylate Energy Charge

Although not a standard or required method, use of the adenylate energy charge system is a new and potentially useful method for testing the general health level of the whole organism. The organism of choice for this analysis is the grass shrimp (Palaeomonetes pugio). A minimum of 25 grass shrimp should be placed into a small container which allows free flow of water, i.e., 0.5-mm nylon mesh bag. The container with organisms should be placed into the in situ bioassay-bioaccumulation cage just prior to deployment. When organisms are collected after the period of exposure, they must be handled with a minimum of disturbance since stress rapidly alters the adenylate energy charge, and they, therefore, must be killed as quickly as possible. The exposure container is allowed to drain briefly, and then the shrimp are immediately submersed in liquid nitrogen to rapidly freeze the organisms. The organisms are allowed to sit in the liquid nitrogen for 1-2 minutes to ensure complete freezing. After freezing, specimens are transferred into a 1-quart thermos with a vented lid and covered with liquid nitrogen. Samples shall be stored and delivered to the laboratory under liquid nitrogen.

PART 3. LABORATORY AND INTERPRETIVE ANALYSES

VII. LABORATORY ANALYSIS OF SAMPLES

INTRODUCTION

As with the selection of variables to be measured, several factors influenced the choice of recommended methodologies. Those criteria deemed important in the selection of methods for inclusion in the second edition of "Methods for Chemical Analysis of Water and Wastes" (U.S. EPA 1976b) were utilized in the initial screening of methods. These criteria are reproduced below:

- a. The method should measure the desired property or constituent with precision, accuracy, and specificity sufficient to meet the data needs of EPA, in the presence of the interfering materials encountered in water and waste samples.
- b. The procedure should utilize the equipment and skills available in modern water pollution control laboratories.
- c. The selected method should be in use in many laboratories or has been sufficiently tested to establish its validity.
- d. The method should be rapid enough to permit routine use for the examination of a large number of samples.

Going beyond these criteria, the authors have attempted to recommend, not necessarily the most elaborate, sophisticated, or state-of-the-art technique, but rather have sought to present the methodologies best tailored to the task at hand. In this respect the methods should be the most economical procedure which will provide the level of sensitivity required for the overall assessment of the site because methods which are more elaborate than needed simply waste money in the generation of superfluous data.

Whenever possible, methods were chosen which had gained wide acceptance

and approval by agencies responsible for developing such regulatory methodology or regulating the disposal of wastes in the ocean. For those necessary variables whose methodologies do not enjoy uniform acceptance and approval, the techniques readily adaptable to water pollution control labs without extensive modification or expenditure were chosen.

For methods which are routine and for which detailed procedures exist in readily available sources, e.g. "Standard Methods" (1976), the basic technique is summarized herein and the reference cited which provides the step-by-step procedures. In those instances where methodology varies considerably with investigators (e.g. benthic infauna) or where the methodology is not always readily available (e.g. enzyme or ATP analyses), these methods have been detailed extensively herein.

It should be emphasized that these methods are presented as guidance and should not be considered as inflexible procedures. Certainly occasions will arise as methodologies are improved or where sufficient historical data exist to justify deviation from these methods. However, before other methods are implemented, the investigator should be certain that

- a. the method is accurate enough to allow the assessment of potential impacts
- b. the method is not increasing analytical costs through the generation of superfluous data
- c. the change will still permit comparison of impact effects with those derived from other dredged material sites

Two final considerations, which are implicit in all the recommended methodologies, are the qualifications of the analysts in charge and the preparation of collection, storage, and processing containers. While the recommended procedures are presented in stepwise fashion, this in no way diminishes the absolute need for an experienced analyst(s).

to supervise all analyses and interpretation and to ensure that adequate internal quality control and verification procedures are implemented.

Proper cleanliness of sample containers, analytical apparatus, and glassware is of paramount importance to the success of any analytical technique especially those for chemical contaminants. Cleaning procedures are mentioned only briefly for each variable to be analyzed. Thus the proper cleaning procedures found in the following references should be reviewed prior to carrying out the field sampling and should become an integral part of the laboratory's responsibility in providing quality results.

Cleaning procedures are found in:

- a. "Manual of Methods for Chemical Analysis of Water and Wastes" (U.S. EPA 1976b)
- b. "Standard Methods for the Examination of Water and Waste Water" (American Public Health Association et al. 1976)
- c. "Analysis of Pesticide Residues in Human and Environmental Samples" (U.S. EPA 1977)

WATER COLUMN ANALYSES

WATER COLUMN TRACE METALS

Cadmium and Lead

Due to the low concentration of Cd and Pb dissolved in seawater, the metals must be concentrated into a small volume prior to analysis. The procedure given on pages 89-90 of the U.S. EPA "Manual of Methods for Chemical Analysis of Water and Wastes" is recommended. Here a 200-ml aliquot of filtered water is chelated with the acid form of APDC-pyrrolidine dithiocarbamic acid in chloroform after pH adjustments. The metal chelate is insoluble in water but soluble in the

organic solvent chloroform. The chloroform extract phase is drawn off and collected. The chloroform is evaporated and the residue containing the metals is dissolved with nitric acid (1:1) then brought to a 10-ml volume with deionized water. Concentration factor is 20x. To check laboratory analyses, sample water is spiked with mixed standards to determine the efficiency of the concentrating procedure.

Analysis of the solution for cadmium and lead is via atomic absorption spectrophotometer (AAS) heated graphite furnace. This analysis is also used for copper and other trace metals except mercury.

Mercury

The analysis of Hg dissolved in seawater is best determined by cold vapor AAS. The bromide-bromate digestion procedures detailed by Farey et al. (1978) for the determination of total Hg in natural waters are recommended. Comments by Farey and Nelson (1978) indicate that loss of Hg by storage can be minimized by using a bromide-bromate-HCl mixture as a preservative. This mixture converts organically bound Hg to inorganic Hg and interference from chlorine and sulfides is eliminated.

The following procedure is recommended in determining dissolved Hg in filtered sample water:

One hundred to 200 ml of sample water is placed in an acid-cleaned BOP bottle. Five ml of concentrated HCl and 2.0 ml of the bromate-bromide solution are added to the sample. After 15 minutes of shaking at room temperature, two drops of hydroxylamine solution are added to terminate the oxidizing reaction by removing the excess bromine.

After conversion of the organic Hg, the remainder of the procedure is identical to the before-mentioned EPA procedure (U. S. EPA 1976b, pp 118-126), e.g., reduce the Hg^{++} to metallic Hg with stannous chloride and purge the vapors into sample cell attached to the AAS. Spiked

seawater samples should be run as an efficiency and accuracy check.

WATER COLUMN CHLORINATED HYDROCARBONS - PCBs AND PESTICIDES

PCBs and CHPs (chlorinated hydrocarbon pesticides) are extracted from water samples by liquid-liquid partition. All reagents and glassware have been cleaned and tested to be free of contamination. This extraction procedure given here briefly is explained in detail in the U.S. EPA "Manual of Analytical Methods for the Analysis of Pesticide Residues in Human and Environmental Samples," Section 11, B (U.S. EPA 1977).

The procedures is as follows:

- a. 500 ml of sample is transferred to a 1000-ml separatory funnel. 10 g of anhydrous Na_2SO_4 is added and shaken well at once. 50 ml of methylene chloride (CH_2Cl_2) is added, shaken two minutes, and allowed to separate (Note: If larger sample volume is desired, reagents are increased proportionately.)
- b. CH_2Cl_2 layer is passed directly through column packed with 5 cm Na_2SO_4 and into a Kadurna-Danish (KD) concentrator.
- c. Extraction and Step b are repeated.
- d. Extract is concentrated in KD evaporator to approximately 4 ml. Walls of KD flask are rinsed with 1 ml of hexane.
- e. Concentrate under nitrogen until smell of PCB disappears.
- f. Polychlorinated biphenyls are separated from certain pesticides using a silicic acid column chromatographic separation technique. This technique is given in detail in Section 9, Chapter VI, of the U.S. EPA "Manual of Analytical Methods for the Analysis of Pesticide Residues and Environmental Samples" (U.S. EPA 1977).
- g. PCB and pesticide determination is by electron capture gas-liquid chromatography (GLC). The quantity of PCB in the sample is determined by electron capture GLC. Compare the total area of response for the residue to the total area of response for a known weight of the Arochlor^R 1254. PCB concentration in the residue is then expressed as an equivalent weight of Arochlor 1254 per unit volume (mg/l). Practical detection limit should be established as 50 ppb and lower values should be reported as trace.

- h. Quantitation of chlorinated hydrocarbon pesticides is by the use of an EPA-type pesticide mixture containing the following components: α -BHC, lindane, heptachlor, β -BHC, aldrin, heptachlor epoxide, p,p' -DDE, α,p' -DDD, α,p' -DDT, chlordane, dieldrin, endrin, p,p' -DDD, and p,p' -DDT. A dual column confirmatory analysis is recommended.
- i. Recovery data of pesticide and PCB spikes to sediment and water samples must accompany each report which includes pesticide and PCB data.

WATER COLUMN HIGH MOLECULAR WEIGHT HYDROCARBONS

High molecular weight (HMW) hydrocarbons are extracted from water by liquid-liquid partition. All reagents and glassware are cleaned and tested to be free of contamination. The extraction and concentration of HMW hydrocarbons given here briefly are explained in detail in U.S. EPA (1977).

- a. Add about 1.5 liters of sample to a separatory funnel (extraction procedure will have to be repeated until the entire sample is extracted).
- b. Adjust pH with concentrated HCl to less than 2.
- c. Extract three times with 50 ml of methylene chloride (CH_2Cl_2). Add extracts to a Kuderna-Danish (KD) concentrator.
- d. Concentrate extracts to about 5 ml in the KD, then to 1.0 ml under purified nitrogen.
- e. Perform the following column chromatography on the above extracts:
 - (1) Silica-alumina column (Figure 20) consists of micro-neutral alumina overlying silica gel 1:2 (v/v) and washed with three column volumes of hexane prior to use. Add 1 to 2 g of anhydrous sodium sulfate (Na_2SO_4) on top of the alumina. Both alumina and silica gel have an activity of one or are activated (activation should be carried out at 240°C for 25 hours prior to use).
 - (2) Carefully apply the extract to the open column with a pasteur pipet being sure never to let the solvent level pass the Na_2SO_4 layer.

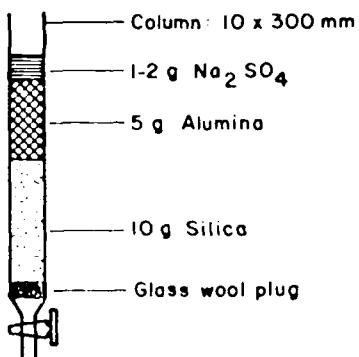


Figure 20. Silica-alumina column

- (3) Elute to the Na_2SO_4 layer with two volumes of petroleum ether. This is the aliphatic fraction.
- (4) Elute with two column volumes of 1:1 (v/v) petroleum ether:benzene and allow column to run dry; this is the aromatic fraction.
- (5) Concentrate fraction to approximately 0.2 ml.
- (6) Analysis of extract is by gas chromatography. Both fractions, aliphatic and aromatic, are analyzed by temperature programmed gas chromatography using a gas chromatograph equipped with a Supelco SP2100 (equivalent to OV-101) glass capillary column (with at least 50,000 effective theoretical plates), a glass capillary inlet system, and flame ionization detectors. Retention time reproducibility of standard compounds eluting up to 60 minutes after injection (e.g., $n\text{-C}_{17}$) is maintained at better than 0.1 minute. Baseline resolution of $n\text{-C}_{17}$ /pristane and $n\text{-C}_{18}$ /phytane is maintained at all times.

Quantification of all samples is completed using response factors determined from even and odd n-alkanes in the $n\text{-C}_{17}$ to $n\text{-C}_{19}$ range; the gas chromatograph is recalibrated at least every 10 injections (5 samples). For quantification of compounds eluting between n-alkanes, the weighted average of response factors from adjacent n-alkanes is used. Unresolved complex mixtures (^{13}C MS) are measured in triplicate by planimetry; the planimeter area is converted

to the gas chromatograph's standard area units at a given attenuation and quantitated using the average response factors of all the n-alkanes occurring within the range of the UCM.

Data report should include the following in addition to instrumental operating conditions, sample identification and complete quantification of any unresolved complex mixture:

Wet weight of sample extracted
Dry weight of sample extracted
Percent dry weight of wet weight
Weight of extractable material recovered (g/g dry wt. of sample)
Total aliphatics and aromatics recovered by weight, as a percent of total extractable material
Total resolved hydrocarbons recovered by % (ug/g dry weight of sample)
Total unresolved hydrocarbons recovered by % (ug/g dry weight of sample)
Sum of the n-alkanes (ug/g dry weight)
Sum of the even n-alkanes (ug/g dry weight)
Sum of the odd n-alkanes (ug/g dry weight)
Ratio: Unresolved hydrocarbons/resolved hydrocarbons
Ratio: (Pristane + phytane)/n-alkanes
Ratio: Odd n-alkanes/even n-alkanes
Ratio: Pristane/n-C₁₇
Ratio: Phytane/n-C₁₈
Ratio: Pristane/phytane
Ratio: n-alkanes/branched hydrocarbons

TOTAL SUSPENDED SOLIDS (TSS) IN WATER COLUMN

Prior to the field work, 0.4-μm pore size, 47-mm diameter, polycarbonate filters (Nucleopore®) are rinsed in deionized water, then placed in small, plastic 47-mm petri dishes, e.g., Millipore Corp. Cat. No. PP1004700. The filters are dried in an oven, 24 hours at 60°C, then placed in a desiccator. After equilibration in the desiccator for 24 hours, the filters are weighed on a six-place balance (0.0001 g), three times on successive days and an average weight for each filter determined. Filters are handled with tongs and kept in the petri dish except when being manipulated as required for the measurement of TSS.

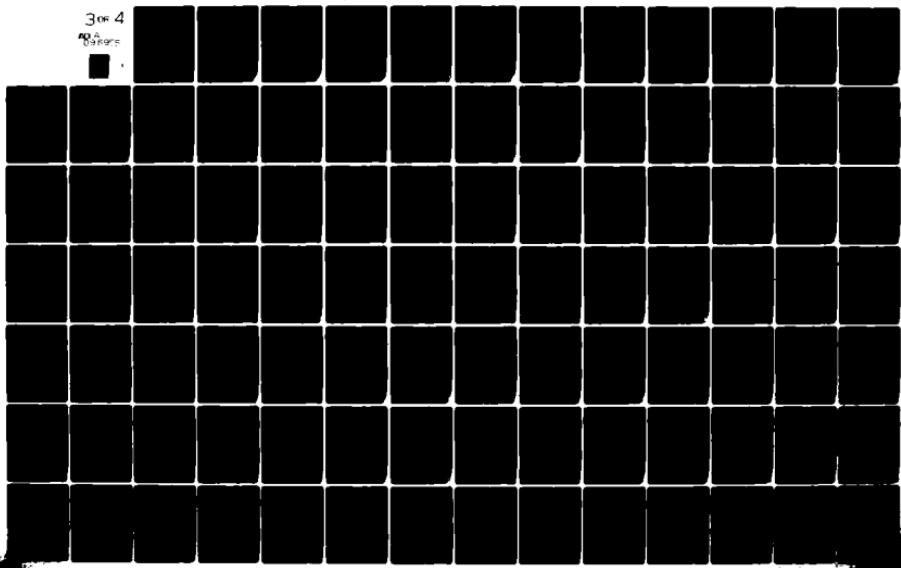
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PROCEDURAL GUIDE FOR DESIGNATION SURVEYS OF OCEAN DREDGED MATER--ETC(U)
JAN 81 W E PEQUEGNAT, L H PEQUEGNAT DACW39-78-C-0097

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Upon return to the laboratory the filters are removed from their respective petri dishes and rinsed with deionized water (three 10-ml rinses) to remove sea salts. The filters are sucked dry with vacuum, placed back in the petri dish, then placed in a drying oven with the cover ajar. The filters are dried at 60°C for 24 hours, then placed in a desiccator. Each filter is weighed on a six-place balance (0.000001 g), then placed back in the desiccator. Each filter is weighed three times on successive days and the three weighings are averaged. At least three filters are used for procedural blanks. TSS is reported as mg/l.

SEDIMENT ANALYSES

GRAIN SIZE ANALYSIS

One of two methods of mechanical analysis is usually employed to determine grain size or sediment texture. The hydrometer method (after Smith and Atkinson 1975) measures the decrease in density of the suspension as particles settle. The pipette method measures the actual weight of particles contained in an aliquot of sediment suspension. The pipette is inserted to a specified depth and an aliquot of the suspension withdrawn at intervals of time.

The hydrometer method is usually used when only the silt and clay fractions are desired. The more definitive pipette method is used when the individual phi fractions are desired.

The pipette procedures for the analyses of various grain sizes described herein adhere strongly to those recommended by Folk (1974) and are summarized in Figure 21. Grain size scales for sediments are presented in Table 29, and a phi-millimeter conversion graph is given in Figure 22.

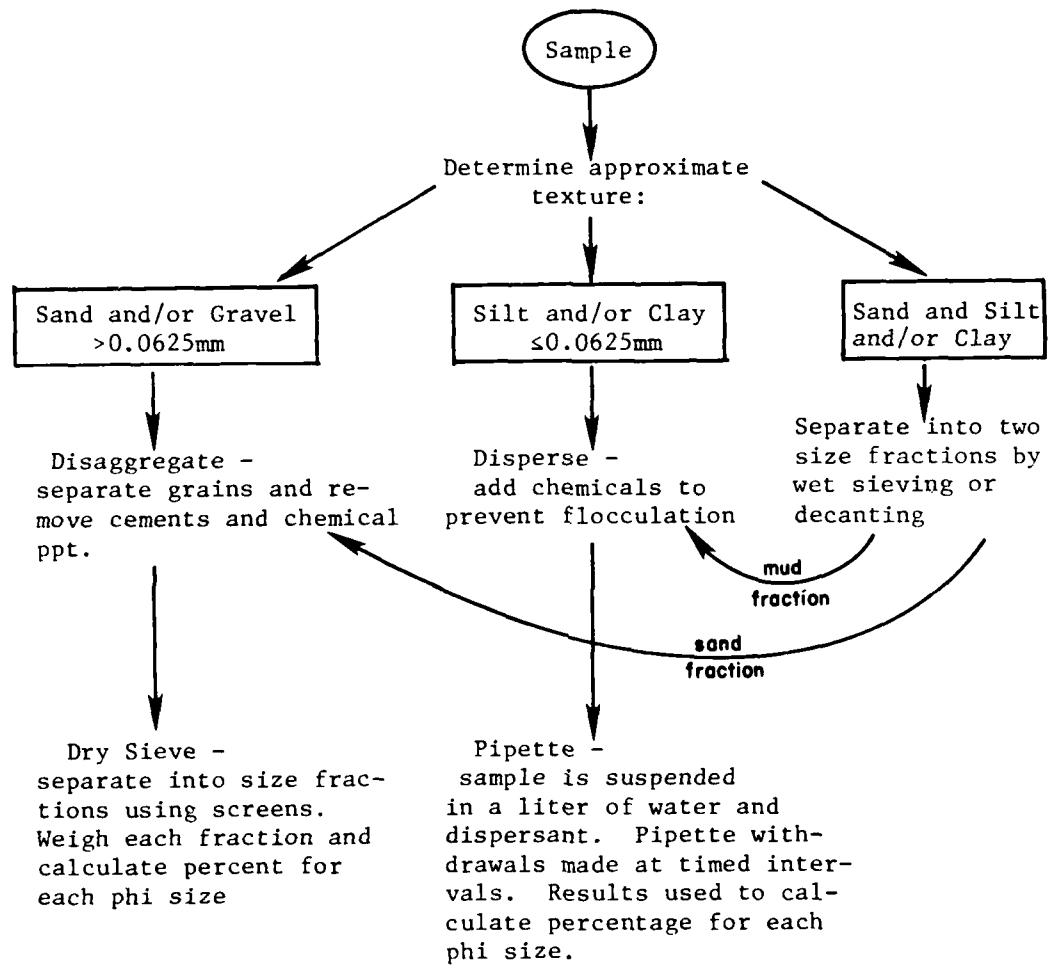


Figure 21. Flowchart of grain size analysis procedure

Table 29
Grain Size Scales for Sediments

The grade scale most commonly used for sediments is the Wentworth (1922) scale which is a logarithmic scale in that each grade limit is twice as large as the next smaller grade limit. The scale starting at 1 mm and changing by a fixed ratio of 2 was introduced by J.A. Udden (1898), who also named the sand grades used today. However, Udden drew the gravel/sand boundary at 1 mm and used different terms in the gravel and mud divisions. For more detailed work, sieves have been constructed at intervals $2^{\frac{1}{2}}$ and $2^{\frac{1}{4}}$. The ϕ (phi) scale, devised by Krumbein, is a much more convenient way of presenting data than if the values are expressed in millimeters and is used almost entirely in recent work.

U.S. STANDARD SIEVE MESH #	MILLI-METERS (1 Kilometer)	MICRONS	PHI	WENTWORTH SIZE CLASS
			-20	
4096			-12	
1024			-10	Boulder (-8 to -12 ϕ)
Use	256		-8	
wire	64		-6	Cobble (-6 to -8 ϕ)
squares	16		-4	Pebble (-2 to -6 ϕ)
5	4		-2	
6	3.36		-1.75	
7	2.83		-1.5	Granule
8	2.38		-1.25	
10	2.00		-1.0	
12	1.68		-0.75	
14	1.41		-0.5	Very coarse sand
16	1.19		-0.25	
18	1.00		0.0	
20	0.84		0.25	
25	0.71		0.5	Coarse sand
30	0.59		0.75	
35	1/2	500	1.0	
40	0.42	420	1.25	
45	0.35	350	1.5	Medium sand
50	0.30	300	1.75	
60	1/4	250	2.0	
70	0.210	210	2.25	
80	0.177	177	2.5	Fine sand
100	0.149	149	2.75	
120	1/8	125	3.0	
140	0.105	105	3.25	
170	0.088	88	3.5	Very fine sand
200	0.074	74	3.75	
230	1/16	62.5	4.0	
270	0.053	53	4.25	
325	0.044	44	4.5	Coarse silt
	0.037	37	4.75	
	1/32	31	5.0	
Analyzed	1/64	15.6	6.0	Medium silt
	1/128	7.8	7.0	Fine silt
by	1/256	3.9	8.0	Very fine silt
	0.0020	2.0	9.0	
Pipette	0.00098	0.98	10.0	
	0.00049	0.49	11.0	
	0.00024	0.24	12.0	
or	0.00012	0.12	13.0	
	0.00006	0.06	14.0	

Bydrometer

GRAVEL SAND SILT MUD

Clay
(some use 2 ϕ or
9 ϕ as the clay
boundary)

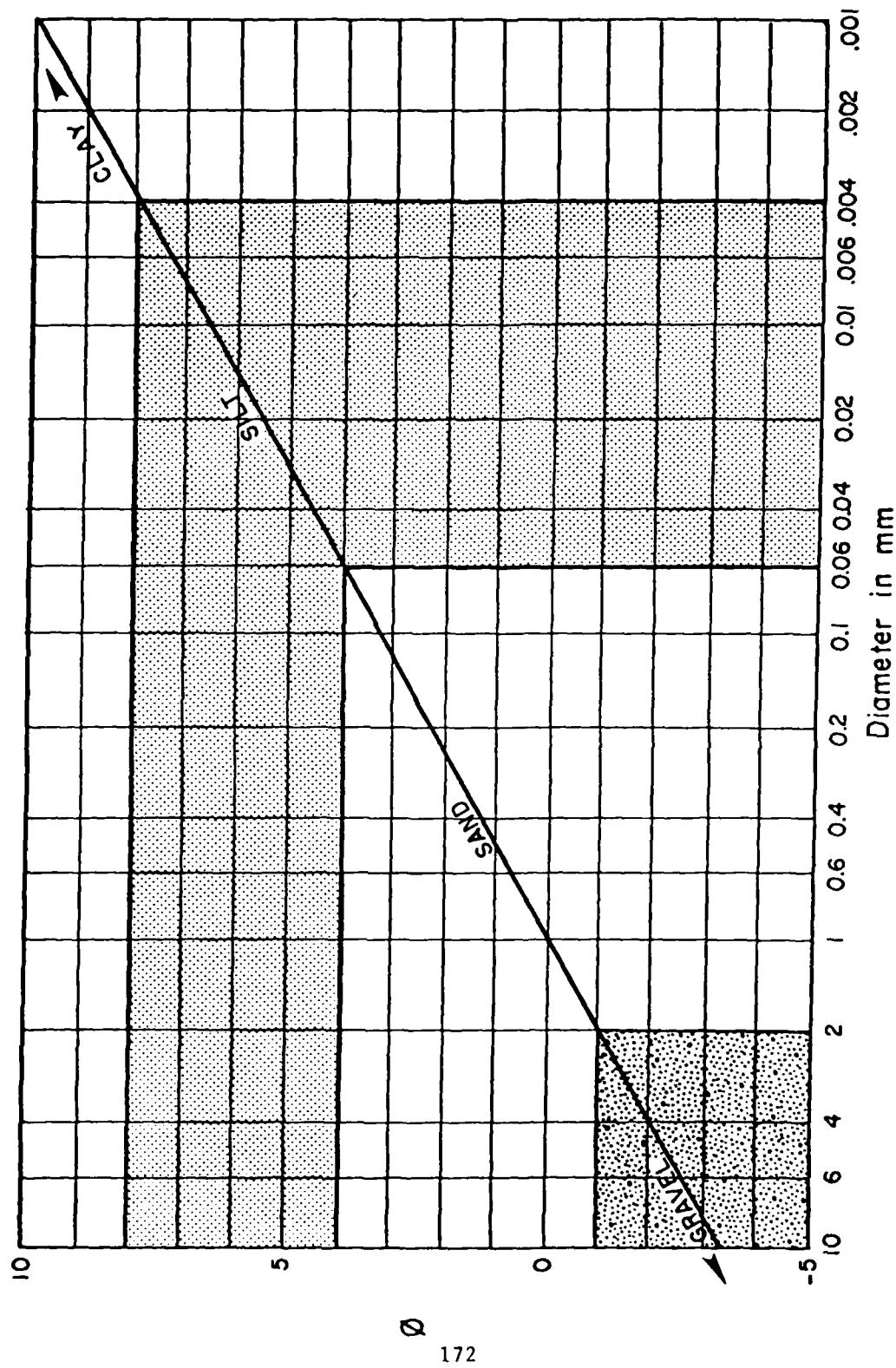


Figure 22. Phi-millimeter conversion graph

Sample Preparation

During the process of deposition, clastic grains may often become cemented into aggregates, acquire overgrowths, or become coated with chemically precipitated materials. It is not necessary to separate individual grains and remove precipitates before analysis for the purposes of these surveys. However, some Districts may find such separation desirable; hence, the proper method is given below (after Folk 1974).

Sand Grain Separation.

Apparatus: Mortar and pestle
Rubber cork
Binocular microscope
62-micron (μm) sieve and collecting pan
Drying hood

Reagents: Distilled water
Hydrochloric acid (HCl), dilute
HCl, 50%
Potassium hydroxide (KOH), concentrated

Procedure: Unconsolidated and weakly consolidated sediments are dried and broken into fragments, as small as possible, using the fingers. A rubber cork can be used to gently pound the material in a mortar to obtain single grains. If a porcelain or iron pestle is required, only up-and-down motions are used.

Carbonate and ferruginous cemented rocks are crushed to particles smaller than 5 mm in diameter. The carbonate cemented material is then placed in dilute HCl until effervescence ceases.

The ferruginous cemented material will probably require warming in 50% HCl to produce a white sand. Samples are then filtered at 62 microns (μm) and washed with distilled water. Liquids collecting in the pan are retained for pipette analysis of silt and clay. The washed sample greater than 62 μm is dried and crushed to produce single grains.

Siliceous cemented rocks are placed in warm KOH, or can be crushed using a mortar and pestle. Note: A microscope is used to ensure that all aggregates have been crushed to single grains.

Mud and Clay Dispersion.

Apparatus: 1-l cylinder
Small dish
Small bottle and screw cap
1-l beaker

Reagents: Distilled water

Dispersant (Note: The most efficient dispersant type and concentration will vary depending on the sediment being analyzed. Several dispersants at several concentrations with equal quantities of sediment are tested to determine the one most suitable. The total amount of dispersant used in any analysis is recorded.)

Procedure: The sample is placed in a dish containing water and dispersant, and the lumps are crushed. The material is transferred to a small bottle using water rinses, capped, and shaken for several minutes. After standing for at least 12 hours, the material is poured into a 1-l beaker and mixed thoroughly with water and dispersant for several minutes. The material is transferred with washes to a 1-l cylinder and dispersant and water are added to bring volume to exactly 1000 ml. After 24 hours the sample is ready for pipette analysis. (Note: If flocculation occurs, the procedure is repeated using more dispersant.)

Separation of Sand From Mud.

Where samples consist of more than a few percent of material finer than 4ϕ (0.0625 mm) (Figure 22 and Table 29), it is necessary to separate the sediment into fractions, and to then analyze the sand fraction by the sieving technique and the silt-clay fraction by the pipette technique.

Apparatus: 62- μm sieve and collecting pan
Drying hood
1-l cylinder
Small bottle

Reagents: Distilled water
Dispersant

Procedure: The sample is placed in a small bottle and shaken well with water and dispersant. The sample is poured onto a wetted 62- μm sieve and bottle contents are rinsed into the sieve. Using less than 1 l of additional water, the sample is washed until water runs clear. The retained fraction is dried, broken into single grains, and analyzed. The filtrate collected in the pan is mixed for several minutes and transferred to a 1-l cylinder. Water and dispersant are used to wash the pan and to bring the volume to exactly 1000 ml. After 24 hours, it is checked for flocculation. If it has occurred, additional dispersant is added and the mixing and settling procedures are repeated prior to analysis.

Sample Analysis:

Grain Size Analysis by Sieving.

Apparatus: Sonic sifter
Nested 8-inch brass sieves with mesh sizes of 2.0, 1.0, 0.5, 0.25, 0.19, 0.12, and 0.06 mm and collecting pan
Balance capable of weighing to nearest 0.01 g

Regeants: Distilled water

Procedure: 50.0 g of sample are weighed to the nearest 0.01 g. With the coarsest sieve at the top and the collecting pan at the bottom, sample is placed on the top screen and sieved for 15 minutes on sonic sifter. Each sieve fraction is carefully weighed, making sure all grains are removed from each screen. Each fraction is checked for aggregates and their weight subtracted from the fraction weight when the aggregates make up less than 25% of the fraction. Where the aggregates contribute more than 25%, the fraction will need to be disaggregated as before and resieved. Data forms should record: mesh size, fraction weight, percent aggregates, corrected fraction weight, cumulative weight, cumulative percent, and individual percent. Cumulative percent is determined by dividing each cumulative weight by the total of the corrected weights. Note: In samples containing gravel, it is necessary to first sieve a kilogram or more of

the sample through a 2-mm mesh sieve. The sand and gravel fractions are weighed. A 50-g subsample of the sample is analyzed as described above. Each fraction weight obtained from this analysis will need to be multiplied by a splitting factor to obtain the weight of the fraction in the whole sample. The splitting factor is calculated as follows:

Total amount of sand passing
through 2-mm sieve

Weight of sand actually analyzed

In the case where gravel is present, recorded data should include: sieve size, fraction weight, corrected weight for the sand fractions (equal to the actual weight times the splitting factor), cumulative weight, and cumulative percentage.

Pipette Analysis of Silt and Clay.

(Samples with grain size smaller than 62 μm or 4 ϕ).

Apparatus: 1-l cylinder

Timer

20-ml pipette

Tared beakers

Note: It is important that room and water temperature be maintained at 20°C

Reagents: Distilled water

Dispersant

Procedure: About 15 g of dispersed sample measured to the nearest 0.01 g is placed in a one-liter cylinder. Volume is brought to exactly 1000 ml with water and dispersant, stirred and allowed to stand for 24 hours. If flocculation occurs, sample is transferred to beaker, more dispersant added, and procedure repeated.

The cylinder is stirred vigorously to distribute material uniformly throughout the column. Timer is started immediately upon ceasing stirring. After 20 seconds, pipette is inserted to a depth of 20 cm and exactly 20 ml of fluid is withdrawn. Withdrawal of other samples at the times and depths specified below (Table 30) can be used to determine the amount of each grain size (smaller than 62 μm) in the sample.

Table 30

Withdrawal Times and Depths for Samples With Grain
Sizes Less Than 62 µm (4Ø) at 20°C

<u>Ø DIAMETER</u>	<u>WITHDRAWAL</u>	
	<u>TIME</u> <u>HRS:MIN:SEC</u>	<u>DEPTH</u> <u>CM</u>
(weight obtained by wet-sieving)		
Coarser than 4		
4	00:00:20	20
5	00:01:56	10
6	00:07:44	10
7	00:31:00	10
8	02:03:00	10
9	04:06:00	5
10	16:24:00	5

The times and depths of withdrawals for particles of any size are given by the equation (Folk 1974)

$$T = \frac{z}{1500 (A) (d^2)}$$

where T is the time in minutes, z is the depth in centimeters, d^2 is the square of the particular diameter in millimeters, and A is constant dependent on the force of gravitation, particle density, and water viscosity (a function of temperature). Folk (1974) presents values of A for various temperatures and particle densities (Table 31).

Table 31
Values of A For Various Temperatures
And Particle Densities (After Folk 1974)

TEMPERATURE °C	DENSITY		
	2.65 (CLAYS, QUARTZ)	3.00	3.35 (AMPHIBOLES)
16	3.23	3.92	4.60
20	3.57	4.33	5.08
24	3.93	4.76	5.60
28	4.30	5.21	6.21
32	4.68	5.67	6.60

The pipette contents should be expelled into separate tared beakers, being sure to flush each pipette with additional distilled water. The beakers are evaporated to dryness and reweighed.

Calculations: Data recorded should include: Ø diameter, depth of withdrawal, time of withdrawal, weight of dried sample in beaker, weight of clean beaker, and weight of sample. The weight of dispersant used in the entire liter of water (computed using molecular weight and normality) should be divided by 50 to give the weight of dispersant per beaker. This weight is subtracted from each calculated fraction weight. The correct sample fraction weights are each multiplied by 50 to give the amount of material in suspension which is finer than Ø diameter. Since the first withdrawal was taken quickly (20 sec) after stirring, its corrected weight times 50 will give the weight of the entire amount of mud in the cylinder (equal to the amount of "fines" which passed through the 62- μ m sieve). If this value is called F, and weight of sand caught on the 62- μ m sieve is S, then the percentage of sand in the sample is $100 \frac{S}{(S+F)}$. If each subsequent pipette sample multiplied by 50 is denoted by P, the cumulative percentages of the total sample at each Ø diameter can be calculated by:

$$\text{Cumulative \% Coarser} = 100 \frac{(S + F - P)}{S + F}$$

These data are plotted on ordinary arithmetic squared graph paper along with gravel and sand data to produce a continuous cumulative curve. According to Folk (1974), the analysis stops at 10Ø. To obtain grain size parameters, the cumulative curve is extended in a straight line from 10Ø to 14Ø at 100%.

SEDIMENT TRACE METALS - CADMIUM, LEAD, AND MERCURY

Seawater Elutriation

Eighty percent of the sediment samples will be treated by seawater elutriation and the remainder by a 0.1 N HCl partial extraction.

Preparation of the liquid phase for the seawater elutriation test for

cadmium, lead, and mercury is given on pages B4 to B7 of U. S. EPA/CE (1977). One aliquot of the liquid phase for the determination of Cd and Pb is preserved by the addition of concentrated HNO₃ to pH<2. A second aliquot of the liquid phase for the determination of Hg is preserved with the addition of several drops of a 1 percent aqueous solution of KMnO₄ (Gaston and Lee 1974) in addition to pH adjustment of less than 2.

Analysis of the seawater elutriate for cadmium and lead is by atomic absorption spectrophotometry (AAS). Extraction procedures (U. S. EPA 1976b, pp 85-91) will be necessary for Cd and Pb due to the low metal concentration in the liquid phase. The aliquot set aside for mercury is analyzed by the cold-vapor method given in U. S. EPA (1976b, pp 118-126).

Partial Extraction of Sediment Cadmium and Lead

Twenty percent of the sediment samples will be partially extracted with 0.1 N HCl. The extract will be analyzed for cadmium and lead concentration.

Sediment samples are freeze-dried in a Virtis Uni-Trap (Model 10-100) equipped with an all-plastic, sample-containing drum. Samples are prepared for freeze-drying by placing a well-mixed portion of the sample sediment collected for trace metal analysis in an acid-cleaned, 40-dram plastic snap-cap vial. Polyfilm is secured over the top of the vial and perforated with a sharpened glass rod to allow water vapor to escape. The prepared vial is frozen in a laboratory freezer prior to being placed in the freezer-dryer. Sediments are freeze-dried for 72 hours, then removed, and the polyfilm replaced with the airtight plastic snap-cap and stored in a desiccator.

The following procedure is used when the sediment contains only small

amounts of carbonate: * Approximately 2 g of freeze-dried, unpowdered, sized (<0.5 mm) sediment is weighed into a tared, 50-ml polyethylene screw-cap centrifuge tube (tube is precleaned in warm 1:1 HNO₃:H₂O overnight and rinsed three times with distilled-deionized water). Twenty-five ml of 0.1 N HCl (ultra pure) is added with a volumetric pipet. The screw-cap is securely tightened and then placed in a horizontal position on the table of a rotary shaker. The tube is shaken for two hours at room temperature (23°C ± 1°C) at a rate of 120 excursions per minute. The extract is separated from the sediment residue by centrifugation (15 minutes at 5000 rpm). The clear leachate is then decanted into an acid-cleaned, 13-dram plastic (Polystyrene) snap-cap vial. The vials may be stored prior to metal analysis by atomic absorption spectrophotometer (AAS) by placing up to sixteen vials upright in a plastic sealable bag (1 gal Zip-lok^R) for a period not to exceed 14 days. Procedural blanks in triplicate receive identical treatment.

Atomic absorption spectrophotometric (AAS) analysis of the seawater elutriate and 0.1 N HCl leachates for cadmium and lead is carried out using a flameless graphite tube furnace attachment. A deuterium arc background corrector is used to correct for nonatomic absorption. Table 32 lists the instrumental parameters required for the analysis. The AAS unit is set up and operated as specified by the manufacturer and as presented on pages 78-93 of the "Manual of Methods for Chemical Analysis of Water and Wastes" (U. S. EPA 1976b). Method of additions is used for quantification. Accuracy of procedures is checked periodically using certified standards, National Bureau of Standards (NBS)

* High carbonate-bearing sediments will require a carbonate removal step prior to adding 25 ml of 0.1 N HCl. Five-hundred-microliter aliquots of 2.5 N HCl are added to the sediment in the centrifuge tube and allowed to react. When foaming ceases, another aliquot of 2.5 N HCl is added. This process is repeated until the next added aliquot causes no reaction (foaming). Twenty-five ml of 0.1 N HCl is then added. The final volume (25 ml + added 2.5 N ml) : wt. sediment = dilution factor.

Table 32
Instrumental Parameters for Flameless Atomic
 Absorption Spectrophotometry

	ELEMENT		
	Cd	Pb	Hg ¹
Analytical wavelength (nm)	228.8	283.3	253.7
Slitwidth (nm)	0.0.7	0.7	
EDL ² energy, (watts)	5	10	5
Argon flow rate ³	30 Int.	30 Int.	Note 4
Dry temperature time	100°C 20 sec	100°C 20 sec	---
Char temperature time	260°C 22 sec	500°C 22 sec	---
Atomize temperature time	2100°C 8 sec	2500°C 8 sec	---
Scale expansion	3x	3x	5x
Sensitivity ⁵	2	25	---

¹Cold vapor technique.

²Electrodeless discharge lamp.

³Flowmeter divisions at 20 psig in interrupt (Int.) mode.

⁴One l/min through bubbling system and sample cell.

⁵Concentration in ng/ml in solution which will give reading of about 0.2 absorbance units.

or U.S. Geological Survey (USGS).

SEDIMENT CHLORINATED HYDROCARBONS - PCBs AND PESTICIDES

Chlorinated hydrocarbon pesticides (CHPs) and PCBs are extracted from a partially dried sediment by column elution with a mixture of 1:1 acetone/hexane. The extract is washed with water to remove the acetone and then the PCBs and CHPs are extracted from the water with 15% CH_2Cl_2 in hexane. The extract is dehydrated, concentrated to a suitable volume, subjected to Florisil partitioning, and desulfurized if necessary. Details of this procedure are given in Section 11, B of the "Manual of Analytical Methods for the Analysis of Pesticide Residues in Human and Environmental Samples" (U.S. EPA 1977). Separation of PCBs and CHPs by silicic acid column chromatography is given in Section 9, C of the above reference. Analysis of the extract by gas chromatography is given on page 165 of this guide.

SEDIMENT OIL AND GREASE

Oil and grease concentration in the sediment is determined by acidifying a weighed sample, adding $\text{MgSO}_4 \cdot \text{H}_2\text{O}$ to remove water, grinding in a mortar, and extracting the oils and greases, using hexane in a Soxhlet extraction apparatus according to the procedures outlined on pages 42-43 of the EPA sediment analysis manual (U.S. EPA 1969).

SEDIMENT HIGH MOLECULAR WEIGHT HYDROCARBONS

High molecular weight hydrocarbons in sediments are determined as follows:

- a. Weigh 250 g wet sediment into a 500-ml, round-bottom flask. (Adjust amount of solvents and reagents used in procedure if a larger or smaller amount of sediment is taken.) Take a separate 20-g aliquot of sediment, dry, and weigh again to obtain the wet/dry ratio (Smith et al. 1977).

- b. Cover sediment with 3:7 toluene/methanol and reflux 7 hours.
- c. Decant extract and store in a clean, 500-ml, round-bottom flask.
- d. Repeat steps b and c and combine all extracts in the round-bottom flask.
- e. Concentrate combined extracts to 25 ml.
- f. Saponify with KOH/methanol for four hours (volume = 50 ml 0.5 N KOH/methanol).
- g. Add extract to separatory funnel and add an equal volume of saturated NaCl solution.
- h. Extract three times with hexane or petroleum ether (volume = volume KOH/methanol added in step f). Collect extracts in a flask.
- i. Wash extract with saturated NaCl (volume = volume KOH/methanol added in step f).
- j. Concentrate extract to about 50 ml in a Kuderna-Danish concentrator and then to 1.0 ml with purified nitrogen.
- k. Ready for column chromatography (see procedure for column chromatography in step e on page 166).
- l. Analyze the aliphatic and aromatic fractions by GLC. This procedure is given in section 6, page 167.

SEDIMENT TOTAL ORGANIC CARBON

Several procedures for determining total organic carbon (TOC) in sediments are recommended. The wet combustion method of Walkley and Black (Allison 1965, pp 1372-1376 and Walkley 1946, pp 251-263) has the advantage of low cost of apparatus and the fact that carbonates, up to 50%, do not interfere. The procedure of determining TOC by dry combustion using a high temperature induction furnace (Allison et al. 1965, pp 1362-1365) has the advantage of rapid analysis; however, carbonates interfere and must either be removed prior to TOC analysis or be accounted for in the final TOC calculation. Whichever method is used, data presentation must be accompanied with a statement as to the method used and a sample calculation showing how the TOC values were determined.

BENTHIC BIOTA

Biological analysis of the trawl samples will include identification and enumeration of the dominant species of macroepifauna, i.e., those organisms such as shrimps, lobsters, crabs, and demersal fishes that live and/or feed on the surface of the sediment. Biological analyses of sediment samples should include the characterization of both the meiofauna, defined as those infaunal organisms which pass through a 0.5-mm mesh sieve and are collected on a 0.062-mm mesh sieve, and the macroinfauna, which are those infaunal organisms retained on a 0.5-mm mesh sieve.

LABORATORY ANALYSIS OF THE MACROEPIFAUNA

The sample will be received at the laboratory preserved in 5% buffered formalin. Initially, the sample is rough sorted into major taxonomic groups, i.e., fish, crab, shrimp, starfish, etc. Each major group is then given to a competent taxonomist. The contracting agency must specify the level of identification effort. Generally, only the principal or predominant species of each taxonomic group need be identified and enumerated. Species of commercial value should be identified and enumerated even if they are not predominant within a group.

It must be remembered that the sample received at the laboratory may represent only a portion of the original trawl sample, since various other portions of the sample may have been taken for chemical analysis. The final listing and enumeration must represent the entire sample.

LABORATORY ANALYSIS OF THE MEIOFAUNA, IF SAMPLED

Apparatus and Reagents

A few minor modifications in any modestly furnished biological labor-

atory will transform it into a laboratory capable of analyzing meiofauna.

Irwin transfer loops are by far the best tools to use for sorting meiofauna. These loops, which can be purchased from Sargent-Welch Scientific Co., allow delicate manipulation of specimens and are excellent for the transfer of organisms to the specimen vials.

The water faucet used for washing meiofauna samples should be fitted with a filter to remove any freshwater contaminants. Blooms of cladocerans and/or rotifers sometimes develop in freshwater holding tanks. These small organisms will appear in the 63- μ sieves if they are not filtered out beforehand. While very elaborate filter systems are available, a gasoline filter similar to the STP type GF-16 filled with glass wool, fitted with tygon tubing, and hose clamped onto the spigot will do the job. The chore of identifying the meiofauna is onerous enough without having to sort out freshwater contaminants introduced from wash water. A flexible hose attached to the excurrent end of the filter is convenient for directing the flow of water onto the sample.

Another preventive modification which should be made to the sink drain is the addition of a sediment trap. The sieving operation introduces large quantities of clay-size particles into the drainage system. A sediment trap will ensure against costly plumbing repairs at some later time.

The greatest monetary investment will be incurred for microscopes. The Wild M-5 dissecting scope is the best available microscope for sorting work and costs about \$3,000. One scope should be available for each person planning to sort. The scope has four objectives (6x, 12x, 25x, and 50x) and an optional 2x magnifier permitting total magnification of up to 100x. Most sorting is performed using the 25x

magnification and the higher magnifications used only for unusually tiny specimens.

A well-made sorting tray is essential for efficient microscopic sorting. The sorting tray must be transparent to allow bottom lighting and it should be shallow to limit water depth and thus prevent sloshing and spillage. Shallow trays also allow the microscopist to focus on the entire water column. This is important for organisms that rest in suspension in the water column. The tray should be small enough to fit on the microscope stage. It is helpful if the sorting tray is marked into a grid. This provides reference points in the dish while sorting and minimizes confusion while counting organisms. A simple sorting dish may be constructed of 1/4-inch (6-mm) and 1/8-inch (3-mm) plexiglass.

A set of 8-inch brass geological sieves with mesh sizes of 500 μ (U.S. No. 35) and 63 μ (U.S. No. 230) should be available for sieving the meiofauna samples in the lab. A set of 3-inch sieves of the same mesh sizes is also advisable for washing stained samples. These four sieves should be adequate for all sieving work required. These can usually be shared by the various technicians.

A sonic cleaner should be available for cleaning sediment with large fecal pellet components. The use of the sonic cleaner will be described later in this section.

Other supplies for the lab work include wash bottles of water and 5% buffered Formalin, 2-ounce squat jars to store sieved samples, a solution of Rose Bengal stain (200 mg/ t 5% buffered Formalin), a large number (allow 10-15 vials per sample) of 1-dram vials for sorted meiofaunal specimens, push-button counters for tabulating the data, gummed labels, data log sheets for final counts, and storage space for all of the processed samples.

Procedure

Sieving. The meiofauna samples have been preserved in a 5% buffered formalin solution in the field for transport to the laboratory. In the laboratory, the 8-inch, 500-micron sieve is placed on top of the 8-inch, 63-micron sieve and both are placed in the sink. The wash water is turned on so that a gentle flow is produced. It is important not to "blast" the sample with water as specimens can be damaged beyond recognition. The preserved sample is emptied into the nested sieves, the jar and jar lid washed until all sediment residue has passed into the sieves. Now the water spray is directed onto the sample, gently washing the sediment through the 500- μ sieve. Any organisms retained by the 500- μ sieve are not meiofauna and can be discarded.

Staining. After the sample has passed through the 500- μ sieve, the two sieves are separated and the 63- μ fraction transferred to a 2-ounce sample jar. Ten ml of the Rose Bengal stain is added to the sample jar, then the jar is filled with 5% buffered Formalin. The sample should stain for a minimum of 24 hours to allow complete diffusion of the stain into the protoplasm of the specimens.

Sorting. After staining, the contents of the 2-ounce jar are poured into the 3-inch-diameter, 63- μ sieve. The sample is washed until all traces of the stain are drained from the sample. All organisms that were alive at the time of collection should now be stained a brilliant red.

The material from the sieve is carefully rinsed with a water wash bottle into the sorting tray. The sediment should lie in a thin layer in the bottom of the sorting dish so that no specimens are hidden beneath the sediment grains. For particularly voluminous samples, the sorting must be done in several splits of the original sample.

Now the sorting tray is carefully placed on the microscope stage and the water surface is scanned for any organisms that are floating. A few nematodes and kinorhynchs will probably be found on the surface. Kinorhynchs always have a tendency to collect on the surface due to hydrostatic forces created by the spines along their bodies. Most kinorhynchs will certainly be overlooked if the water surface is not scanned initially.

Any organisms found should be transferred with an Irwin loop from the sorting tray to a 1-dram vial partially filled with preservative. The loop should always be checked under the microscope after a specimen transfer to be certain that it was deposited in the vial.

The organism is recorded on a counter and sorting of the remainder of the sample is continued. Each vial should be labeled with appropriate descriptive information when it is first used. When sorting is finished, the number of specimens contained in the vial is recorded on the label.

If a sieved sample has a large fecal pellet component, the water will become turbid during sorting as the fecal pellets disaggregate thus hindering sorting efficiency. This problem can be alleviated by placing the sample in a small beaker and placing the beaker in an ultrasonic cleaner such as the Cole-Parmer No. 8845-30. About 50 ml of water is added to the beaker, then the basin of the ultrasonic cleaner is filled with water until the level is about even with the water level in the beaker. The cleaner is run for 60 seconds to break the fecal pellets, then the sample is washed on the 63- μ sieve again. The sample should now be "cleaned" and ready for sorting.

Sonification should not be used unless fecal pellets are a great problem. Many times fecal pellets constitute 99% of a sediment sample, and the use of a sonifier would be justified. However, damage to organisms does occur during cleaning by this method. The vigorous

vibration tends to shear appendages of copepods and polychaetes. Still the technique is a valuable time-saving tool to consider for particularly troublesome samples.

Storing. After a sample has been sorted to the satisfaction of the investigator, each vial should be filled with 5% buffered Formalin and capped tightly. If prolonged storage is anticipated, the 1-dram vials can be placed in larger containers and these filled with water to help retard the loss of the fixative to evaporation. Regardless, samples should be checked annually for the level of contents and refilled as necessary.

Statistics. All counts of meiofaunal organisms should be tabulated and organized according to sample label and meiofaunal taxon for easy access and subsequent statistical treatment. Each investigator will want to handle the statistical aspects of the analysis using his own preferred tests and talents. Consequently, statistical procedures will not be discussed here (see Chapter VIII, this report). It is emphasized, however, that the statistical treatment of the data should be carefully considered before the sampling work is conducted. Firm conclusions must be supported by statistically valid results if they are to be convincing. A well-planned statistical approach to a problem should form the foundation for the development of an effective sampling program.

LABORATORY ANALYSIS OF THE MACROINFAUNA

Apparatus and Reagents

A laboratory furnished with the apparatus and reagents required for meiofaunal analysis is well suited for macrofaunal analyses with few exceptions.

Although an overhead illuminated magnification system can be used to sort the majority of macrofaunal organisms, a dissecting microscope similar to that used in meiofaunal analysis is often required.

Dissecting forceps with fine points are helpful in transferring organisms to storage containers. A concentrated sugar solution (5 lb sugar per gallon of water) is helpful in "floating" organisms to the surface for sorting. A supply of 5-dram vials in addition to smaller vials is required for organism storage.

Procedure

Preserved samples should be washed onto a 0.5-mm mesh sieve and gently washed with water to facilitate removal of fine silt and clay. The washed sample should be placed in Rose Bengal-Formalin stain solution for at least 24 hours.

Stained solutions should be washed onto the 0.5-mm sieve and transferred to the concentrated sugar solution. The organisms which float to the surface should be decanted to a sorting tray and sorted.

Only the shelled organisms (Mollusca, Ostracoda, and Foraminifera) and some of the tube-forming polychaetes (e.g. Serpulidae) remain in the sediment. For complete analysis of these groups, the sediment must be scanned for these specimens. Bivalves present a problem in that the shell prevents the sorter from determining the presence of stained tissue within. Consequently, any hinged bivalves should be removed and counted during sorting. When further taxonomic work is performed, the specialist can open the shell and classify it living or dead.

Effective sorting of the decanted specimens can be conducted with the 6x or 12x magnification of a microscope. The shelled specimens can be more conveniently sorted from the sediment by placing the sample in a large, white pan. Using an overhead illuminated magnification system (Cole-Parmer No. 9803-10, for example), the sample can be sorted and

organisms removed with forceps.

As with the meiofauna, the macrofaunal organisms should be placed in vials according to appropriate taxonomic groups at or above the species level. Five-dram vials are more appropriate for holding macrofauna specimens. All vials should be labeled and their contents enumerated for future reference.

After sorting is complete, final counts should be tabulated on a log sheet. The vials should be filled with preservative and capped tightly for storage.

TISSUE ANALYSES

TISSUE TRACE METALS

Dissection Procedure

Faunal samples to be analyzed for Cd, Pb, and Hg are thawed in a laminar flow clean bench and processed according to specimen type. Shrimp are deheaded, the exoskeleton removed, and deveined leaving only edible tissue to be analyzed. Fish specimens are rinsed with deionized water, the skin flayed back, and the axial muscle removed for analysis. Shellfish are rinsed with deionized water, blotted dry, and then opened. Only the soft parts are analyzed. All dissection is accomplished on an acid-cleaned acrylic block in a class 100 laminar flow clean bench using plastic forceps and acid-rinsed stainless steel blade/plastic handle scalpel. Approximately 10 grams wet weight of tissue is required for each Cd-Pb analysis and 10 grams wet weight for Hg analysis.

Cadmium and Lead

After dissection the tissues are freeze-dried and powdered with an agate

mortar. Approximately 1.0 g of the dried tissue powder is weighed into a 200-ml, tall-form Pyrex[®] beaker. Ten ml of ultrapure HNO₃ is added and the sample allowed to sit overnight at room temperature with Teflon watchglass covers. The samples are then placed on a hot plate and slowly heated until NO₂ fuming ceases. The temperature is increased (200°C) until dryness and charring is achieved. Five ml HNO₃ and 2.0 ml of HClO₄ are added and the residue is brought into solution by gentle heating. The sample is allowed to reflux for two hours, then the watchglass is removed, heat is increased, and the sample is evaporated to dryness. One ml of HNO₃ is added while applying heat to bring the white residue into solution. Five ml of deionized water (Milli-Q[®]) is added and the contents of the beaker allowed to cool. The contents are transferred to a tared 13-dram plastic snap-cap vial. Three-ml aliquots of deionized water are used to rinse the digestion beaker until approximately 15 ml of solution is in the plastic vial. The vial is reweighed and a dilution factor calculated. Reagent blanks and NBS-certified standard orchard leaves and bovine liver samples are treated in an identical fashion.

Instrumental analysis for determining Cd and Hg concentration will be by flameless AAS. Method of additions is used to quantify. Accuracy is determined by comparing values obtained for NBS standards to the certified value.

Mercury

Approximately 10 g wet weight of tissue is oven-dried at 60°C for 24 hours, then powdered with an agate mortar. A method for tissue digestion described by Velghe et al. (1978) will be used. Briefly, the method is as follows: 0.1 - 0.2 g of tissue and a double quantity of KMnO₄ (crystals) are weighed in a 50-ml beaker. Four ml conc. H₂SO₄ is added under shaking and the mixture set on a warm hot plate. After dissolution of the tissue, which normally takes less than 1 minute, the mixture is left on the hot plate for 1 more minute. The beaker is

cooled in an ice bath and 8 ml of H₂O added slowly. After further cooling, 500 µl N₂OH-HCl is added to reduce the excess KMnO₄. The digest solution is then quantitatively transferred to a BOD bottle, diluted to 150 ml, and the solution analyzed for Hg using the cold vapor technique. Reagent blanks, calibration standards, and NBS orchard leaves and NBS bovine liver are run parallel with the sample tissue.

CHLORINATED HYDROCARBONS IN TISSUES - PCBs AND PESTICIDES

Organisms to be analyzed for PCBs and CHPs are thawed in a laminar flow clean hood. Edible tissue is dissected using organic-free stainless steel or aluminum instruments and aluminum foil-covered blocks. A minimum of 10 g wet weight of tissue is required for each determination. Sample preparation and extraction procedure are detailed in Section 5, A(1) of U.S. EPA (1977). PCBs and CHPs in the final extract are recovered by silicic acid column chromatography. Silicic acid column chromatography is given in Section 9, C of the above reference. Analysis of the extracts for PCBs and CHPs by electron capture detector GLC is given in section 6 on page 167 of this guide.

HIGH MOLECULAR WEIGHT HYDROCARBONS IN TISSUES

The method given below is adapted from Smith et al. (1977).

About 100 g of tissue is homogenized. The complete organism is used except for shellfish. Here the soft parts are taken for analysis and the shell discarded. Two hundred fifty ml of methanol and 0.05 g KOH/g tissue are added. The mixture is refluxed four hours. Five hundred ml of organic-free water is added and the mixture is refluxed over night. The mixture is then filtered through Whatman Number 1 filter paper held by a buchner filter funnel. The filtrate is extracted three times with 50-ml aliquots of hexane. The filter paper is rinsed with 50 ml of hexane. The total hexane extract is backwashed with

250 ml of saturated NaCl aqueous solution. The aqueous layer is discarded. The extract is concentrated in a Kuderna-Danish to approximately 5 ml. The extract is then dried with Na₂SO₄ and transferred to vials. It is then further concentrated to about 1 ml under a nitrogen stream. The silica-alumina column chromatography is performed as for water extract given on page 166 of this guide. The extracts are analyzed for high molecular weight hydrocarbons as outlined on pages 167 and 168.

ENZYMES - OPTIONAL

The enzyme assays performed on the livers from experimental fish are all straightforward and, after the initial sample preparation, fast. In addition, they require only that the lab be equipped with a dual beam spectrophotometer, a refrigerated centrifuge, and an instrument for homogenizing tissues. Concurrent with the catalase, ATPase, and cytochrome P-450 analyses, a protein determination of the liver samples is performed to provide a convenient reference point with which the data can be normalized.

Reagents

The following reagents may be obtained from Sigma Chemical Company:

- a. ATP (A-3377)
- b. Albumin, Bovine Serum (A-4503)
- c. Glycerol (G-7757)
- d. Lactic Dehydrogenase (L-1254)
- e. Morpholinopropane Sulfonic Acid (MOPS) (M-1254)
- f. β -Nicotinamide Adenine Dinucleotide, Reduced form (NADH) (N-8129)
- g. Phenazine Ethosulfate (PES) (P-4883)
- h. Phenol, Folin and Ciocalteau's (F-9252)

i. Phospho(enol)Pyruvate (P-7127)

j. Pyruvate Kinase (P-9136)

Apparatus

A tissue homogenizer similar to a Virtis "23" Tissue Homogenizer is used to homogenize the liver samples. Centrifugations are carried out in a Damon/IEC B-20A refrigerated centrifuge. All spectrophotometric analyses are performed with a Bausch and Lomb Shimadzu Spectronic UV200 dual beam spectrophotometer and appropriate recorder.

Specimen Preparation

Within one hour of collection, livers of experimental fish (Fundulus similis and F. grandis) are excised, pooled in groups of five, and frozen in a solution of 20% glycerol (v/v) in 50 mM MOPS buffer (pH to 7.6 with NaOH) for transport to the lab. In the lab the samples are defrosted, the glycerol-MOPS solution is pipetted off to remove excess hemoglobin, and fresh glycerol-MOPS solution is added to bring the volume to 10 ml.

The tissue preparation is homogenized (for 90 seconds in 3 30 second intervals) in an ice bath, a 0.1-ml aliquot is removed for protein determination, and the remainder of the homogenate is centrifuged at 3500 g's for 10 minutes at 4°C. The pellet is discarded, and the supernatant is centrifuged again at 16,000 g's for 20 minutes at 4°C. The pellet is saved for the ATPase determination and frozen until used. One tenth of a milliliter of the supernatant is removed for the catalase determination, and the remainder of the supernatant is made 10 mM with CaCl₂, mixed by inversion, allowed to sit for 30 minutes in the cold (0-5°C), then centrifuged at 16,000 g's for 30 minutes at 4°C. The supernatant is discarded and the pellet is resuspended in 5 ml of fresh glycerol-MOPS solution and used for the cytochrome P-450 determination.

Protein Determination

The method of total liver protein determination is that of Lowry et al. (1951).

Working Solutions. The following solutions are used:

- a. Copper Sulfate Solution (mixed 100:1:1 just before use)
 - (1) 2% (w/v) Na_2CO_3 in 0.1 N NaOH
 - (2) 2% (w/v) KNa Tartrate in distilled H_2O
 - (3) 1% (w/v) CuSO_4 in distilled H_2O
- b. Phenol Reagent - 2 N stock solution of Folin and Ciocalteau's Phenol Reagent is diluted to 1 N just before use.
- c. Protein Standard Stock Solution - Bovine Serum Albumin (BSA) is mixed in distilled water to a final concentration of 500 mg/ml.

Procedure.

- a. Calculate the necessary amounts of BSA and distilled water to obtain desired protein concentrations for a standard curve.
Example:

volume BSA stock solution	0	50 μl	100 μl	200 μl
volume distilled water	1 ml	0.95 ml	0.90 ml	0.80 ml
protein concentration	0 $\mu\text{g}/\text{ml}$	25 $\mu\text{g}/\text{ml}$	50 $\mu\text{g}/\text{ml}$	100 $\mu\text{g}/\text{ml}$

- b. To each test tube add 1.0 ml of protein solution (for liver homogenate samples, use 5-10 μl of homogenate made up to 1.0 ml with distilled water).
- c. Add 5 ml of the copper sulfate solution and mix immediately.
- d. After exactly 10 minutes add 0.5 ml of the 1 N phenol reagent.
- e. Read color 30 minutes later at 660 nm on the spectrophotometer.
- f. Use the standard curve to calculate the actual protein concentrations of the liver homogenate samples.

Catalase Determination

Catalase activity is determined by measuring the rate at which a known

concentration of hydrogen peroxide (H_2O_2) is decomposed by the enzyme. The rate of decrease in optical density of the H_2O_2 at 240 nm is a direct measure of the catalase activity.

Working solutions. The only solutions required for catalase determination are 50 mM MOPS, pH 7.6, and 3% hydrogen peroxide (H_2O_2).

Procedure.

- a. Set the spectrophotometer to read absorption at 240 nm (ultra-violet light).
- b. Set the recorder at 0-1.0 absorbance full-scale sensitivity with a chart speed of 5 in./min.
- c. To both the sample and reference quartz cuvettes add 2.4 ml of 50-mM MOPS solution and 0.1 ml of 3% H_2O_2 .
- d. With a microliter syringe place 5-10 μl of the catalase supernatant on a piece of Parafilm. Add this to the sample cuvette by inversion, quickly place the cuvette back in the spectrophotometer, and begin recording the rate of decreasing absorbance in the sample.
- e. Utilizing the extinction coefficient for H_2O_2 , $\epsilon H_2O_2 = 35/\text{mole/liter}$ (this may have to be determined for the spectrophotometer being used), the amount of catalase in the liver sample is expressed in B.U./mg liver protein. 1 B.U. = Bergmeyer Unit = amount of catalase which will decompose 1000 mg of H_2O_2 in one minute.

Example Calculation.

$$(\Delta OD/min \div 35/\text{mole/liter}) \times (\text{vol. of sample cuvette}) = \frac{\text{Moles } H_2O_2/\text{min}}{\text{Decomposed}}$$

$$\text{Moles } H_2O_2/\text{min} \times \text{mg } H_2O/\text{mole } H_2O = \text{mg } H_2O/\text{min}$$

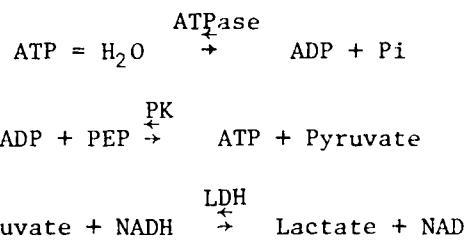
$$\text{mg } H_2O/\text{min} \div 100 \text{ mg/min} = \text{B.U.}$$

$$\text{B.U.} \times \frac{\text{Vol. of Supernatant (usually 9-10 ml)}}{\text{Vol. of Supernatant Assayed (5-10 } \mu\text{l})} = \text{Total B.U.}$$

Divide by total liver protein to get total B.U./mg liver protein

ATPase Determination

By coupling the ATPase reaction with the pyruvate kinase and lactate dehydrogenase catalyzed reactions shown below, the rate of decrease in optical density at 340 nm (i.e. the rate of NADH decrease) is a direct measure of ATPase activity if pyruvate kinase (PK) and lactate dehydrogenase (LDH) are present in excess.



PEP = Phospho(enol) Pyruvate

NADH = Nicotinamide Adenine Dinucleotide, Reduced Form

NAD = Nicotinamide Adenine Dinucleotide, Oxidized Form

Working Solutions. The millimolar concentrations of the following reagents are made up in 200 ml of distilled water:

5 mM MgCl₂
10 mM NaCl
20 mM K₂HPO₄
0.08 mM Phospho(enol) Pyruvate
1.0 mM ATP
0.2 mM NADH

To the above solution is also added 40 mg of bovine serum albumin, 2000 units of pyruvate kinase, and 2200 units of lactic dehydrogenase.

Procedure.

- a. Add two and a half milliliters of the above solution to both the sample and reference cuvettes.
- b. Add ten microliters of the sample ATPase pellet to the sample cuvette with a microliter syringe and mix immediately by inversion.
- c. Record the decrease in absorbance of NADH at 340 nm at 0-1.0 absorbance full-scale sensitivity with a chart speed of 2 in./min.
- d. Using the extinction coefficient of NADH, ϵ NADH = 6.22/Mole/liter, calculate the number of ATPase activity units in the liver sample and express in terms of activity units per milligram liver protein, 1 activity unit being equal to amount of ATPase which will decompose 1 mg NADH in 1 minute.

Example Calculation.

$$(\Delta \text{ OD/min} : 6.22/\text{mMole/liter}) \times \text{Vol. of sample cuvette} = \text{mMoles NADH/l}$$

$$\text{mMoles NADH/min} \times \text{mg NADH/mMoles NADH} = \text{mg NADH/min}$$

$$\text{mg NADH/min} : 1000 \text{ mg NADH/min} = \text{Activity Units}$$

$$\text{Activity Units} \times \frac{\text{Vol. of ATPase Pellet}}{\text{Vol. of Pellet Assayed (usually 10 } \mu\text{l)}} = \text{Total Activity Units}$$

Finally, divide total activity units by mg liver protein to obtain final answer.

Cytochrome P-450 Determination

Cytochrome P-450 (and P-420) is determined directly by colorimetric analysis of the liver preparation. The assay used is a modification of the method of Johannesen and DePierre (1978).

Working Solutions. The following stock solutions should be made up beforehand:

- a. Phenazine Ethosulfate - Ascorbate (PES-Asc) - A solution of 250 μ M PES and 25 mM Ascorbate is made up in distilled water. (This solution is stable when frozen.)
- b. NADH - A 50-mM solution of NADH is made up in 50 mM MOPS buffer, pH 7.6. This solution should be made fresh daily.

Procedure.

- a. For every 1.0 ml of the P-450 sample solution add 10 μ l of the PES-Asc solution, then slowly bubble (5-9 ml/min) the sample with CO gas for one minute. The solution is equally divided between the sample and reference cuvettes, the cuvettes are capped, and a baseline scan is run from 500-400 nm on the spectrophotometer (Figure 23, Line A) using 0-0.1 absorbance full scale and 5 in./min chart speed. If the baseline is not fairly straight, remix the solution and rerun the baseline.

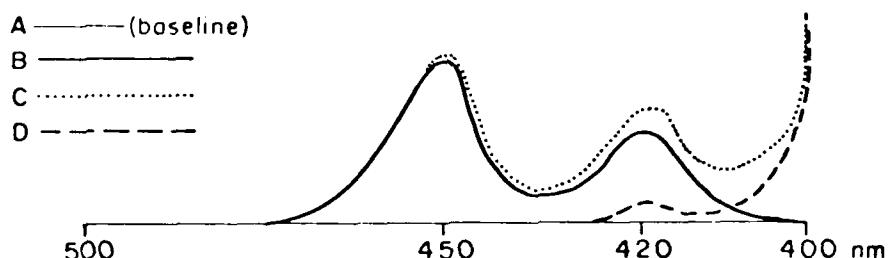


Figure 23. Theoretical scans for a typical Cytochrome P-450 assay

- b. To the sample cuvette add 10 μ l of NADH solution for every 1.0 ml of the sample solution, mix by inversion, and again scan from 500-400 nm (Figure 23, Line B). The peak around 420 nm is due to reduced Cytochrome b₅ and some P-420 (solubilized form of P-450).
- c. Add a few crystals of sodium dithionite to the sample cuvette, mix by inversion, and scan again (Line C). The peak at 450 nm is reduced P-450, while the peak at about 420 nm is reduced P-420 and b₅.

- d. To the reference cuvette add 10 μ l of NADH solution for every 1.0 ml of sample solution, mix by inversion, and scan (Line D). This step reduces the Cytochrome b₅ in the reference cuvette so that the peak at 420 nm represents almost all P-420.
- e. After the peak heights are measured, calculate the amounts of P-450 and P-420 using their respective extinction coefficients (ϵ 450 = 105/mMole/liter; ϵ 420 = 110/mMole/liter). Values are expressed as nMoles P-450 (or P-420) per milligram liver protein.

Example Calculation (P-450)

$$(\Delta OD : 105/\text{mMole/l}) \times \text{Vol. of Sample Cuvette} = \text{nMoles P-450}$$
$$\text{nMoles P-450} \times \frac{\text{Vol. P-450 Suspension (Usually 5 ml)}}{\text{Vol. Sample Cuvette}} = \text{Total nMoles P-450}$$

To express final answer divide Total nMoles P-450 by mg liver protein

ADENYLATE ENERGY CHARGE - OPTIONAL

SPECIMEN COLLECTION

Specimens to be used for this analysis are the grass shrimp (Paleomonetes pugio) which were exposed in the in situ bioassay-bioaccumulation cages (see Chapter VI). Samples will arrive at the laboratory frozen under liquid nitrogen. Samples must be stored in liquid nitrogen until analyzed.

SAMPLE PREPARATION

All sample preparation steps must be carried out on ice to prevent ATP degradation.

A wet weight for each organism is obtained by emptying the frozen specimen onto a tared weigh paper. It is then placed in a ceramic

mortar which has been chilled to -20°C in a freezer. After adding 3 ml of ice-cold Perchloric Acid (PCA) to the mortar, the organism is ground up into a fine slurry with a chilled ceramic pestle. The slurry is then emptied into a small beaker with the aid of a pipette and/or rubber policeman. The sides of the mortar and pestle are rinsed with 5 ml of 50 mM Morpholinopropane sulfonic acid solution (MOPS) which is then added to the beaker. The sample is then adjusted to neutrality by adding 0.6 ml of 6 N KOH followed by titration with 1 N KOH to pH 7. The volume of KOH added is recorded, the sample is poured into a centrifuge tube, and the sample is stored on ice. This procedure is repeated until 8 samples have been obtained (or whatever number is convenient for the centrifuge to be used), which are then centrifuged at 7000 x g for 15 minutes at 0-4°C. The supernatant is poured into a clean test tube and frozen at -20°C until the sample is ready to be assayed.

With each group of samples a blank and an ATP standard are prepared also. The blank consists of 3 ml of PCA, 5 ml of 50 mM MOPS, 0.6 ml of 6 N KOH, and the necessary amount of 1 N KOH required to reach pH 7. The ATP standard contains all of this plus 0.1 ml of a 100 µM ATP solution, and it is made up to a total volume of 10 ml with 50 mM MOPS.

REAGENT SOLUTIONS

The following solutions should be made up for use with the adenylate energy charge determination:

- a. Morpholinopropane Sulfonic Acid (MOPS) (Sigma M-1254) - Prepare a 1-M stock solution by dissolving 20.9 g in approximately 70 ml of distilled water, pH to 7.6 with NaOH, and make up to 100 ml volume with distilled water. Store at 4°C.
- b. Phospho(enol)Pyruvate (PEP) (Sigma P-7127) - To 12 ml of 10 mM MOPS add 20 mg PEP, 370 mg MgSO₄·7H₂O, and 400 mg KC1.

- c. Pyruvate Kinase (Sigma P-1381) - Make a 1:1 dilution of the stock solution with distilled water.
- d. Myokinase (Sigma M-3003) - Use the stock solution as is.

APPARATUS

Centrifugations are carried out in a Damon/IEC B20-A refrigerated centrifuge. All ATP assays are performed with the DuPont 760 Luminescence Biometer and the associated DuPont luciferin-luciferase reagent kits.

ATP DETERMINATION - OPTIONAL

All ATP assays are performed on the DuPont 760 Luminescence Biometer according to the procedures outlined in the accompanying instruction manual.

Before the samples are assayed, a standard curve is prepared by making 1:2, 1:5, 1:10, 1:50, 1:100, 1:500, and 1:1000 dilutions of the ATP standard and assaying 10 μ l of each in the Biometer. The readings are recorded, and the linear regression of known ATP concentration versus Biometer readout is calculated. Ten microliters of each sample are assayed in duplicate and the ATP concentrations of the samples are then determined from this curve (NOTE: In the more concentrated ATP ranges the Biometer readings are frequently nonlinear; in this case, samples with ATP concentrations outside of the linear range of the instrument should be diluted until they fall within the acceptable range).

The DuPont Luminescence Biometer gives sample readouts in terms of fg ATP/ml ($fg = 10^{-15}g$). To convert this number to μ Moles ATP/specimen, the following equation is utilized:

$$\frac{fg \text{ ATP}/\text{ml}}{fg \text{ ATP}/\mu\text{Mole ATP}} \times \frac{\text{Volume (ml) of Sample Extract}}{\text{Dilution Factor(s)}} = \frac{\mu\text{Moles ATP}}{\text{Specimen}}$$

The data are normalized by expressing the results in terms of μ Moles ATP/mg of specimen weight.

AMP AND ADP DETERMINATION - OPTIONAL

The AMP and ADP concentrations for each sample are determined by enzymatically converting the two to ATP, which can then be measured in the Luminescence Biometer.

For each sample two test tubes are used, one is labeled "AMP", the other is labeled "ADP". To each test tube 0.3 ml of the PEP solution and 0.7 ml of 10 mM MOPS are added followed by 10 μ l of the sample extract. Ten μ l of the Pyruvate Kinase solution is added to each tube, and 2.5 μ l of Myokinase only to the tube labeled AMP. The sample is incubated at room temperature for 10 minutes.* Ten μ l from each tube is assayed in the Biometer and the readout is recorded in the same manner as described for the ATP determination. The final AMP and ADP concentrations are determined as follows:

$$\text{AMP} = \text{ATP}_{\text{"AMP" tube}} - \text{ATP}_{\text{"ADP" tube}}$$

$$\text{ADP} = \text{ATP}_{\text{"ADP" tube}} - \text{ATP}_{\text{original}}$$

The adenylate energy charge ratio can then be expressed by the following equation:

$$\text{E.C.} = \frac{\text{ATP} + 1/2 \text{ ADP}}{\text{ATP} + \text{ADP} + \text{AMP}}$$

* This is an approximate time only--determine time for optimum test yield by assaying 10 μ l of solution every two minutes for ten minutes, starting five minutes after adding the enzymes and continuing to 15 minutes after enzyme addition.

VIII. PRESENTATION OF LABORATORY AND FIELD DATA

GENERAL

Selection of an appropriate method to use for effectively presenting environmental data depends not only on the nature of the data but also on its use. Most of the information derived from the water column during the ocean survey, such as the distribution of dissolved oxygen, salinity, and temperature, can best be presented graphically on ordinary graph paper. Data points for the above variables plotted against depth and connected by a smooth curve will give an immediate overview of the physical nature of the water column. Ordinarily, no statistical treatment of these data will be required, because they will be used primarily for site characterization. In general those variables measured in the survey that will be used in impact evaluation or monitoring studies must be presented in a more elaborate manner including statistical evaluation.

Although many aspects of marine ecosystems will be affected by the dumping of dredged material, the stresses and effects on some parts of the system are so transitory or difficult to quantify that they are of limited value to the purposes of this guide. Also, the decision as to what part of the marine ecosystem should be protected for the welfare of the biota in any Corps District often has social and economic aspects so that final decisions cannot or will not be based upon scientific data alone. If, however, degradation of marine water quality by dredged material is kept within reasonable boundaries, it seems likely that the marine ecosystem can be protected. It is not possible to provide recommended levels of pollutants that are applicable to every Corps District, because the marine environment does vary. Nevertheless, some general recommendations for particular pollutants will be presented at the end of this chapter.

As discussed earlier, changes occurring in the water column when dredged material is dumped generally fit into the category of transitory changes; hence, emphasis will be placed upon interpreting and evaluating quantifiable data derived from the bottom environment. It is generally accepted by benthic biologists that the size, shape, and arrangement of the sediments have a controlling influence on the constitution of benthic communities. Moreover, the dumping of dredged material can be expected to have some measurable effects on the sediments - not alone in terms of their texture, but also of their chemistry. These changes in turn may then affect some species of the benthic community more than others resulting in measurable change. It follows that alterations of the constitution of the sediment bed and of the structure of benthic communities can reveal the stresses of the dumping of dredged material in the site and subsequently in other areas of possible impact.

In order to assess these effects, one must compare data derived from affected areas to those obtained from samples collected in a reference area that is similar to the affected areas but is presumably unaffected by dumping operations or their aftermath. Ordinarily, one shall be dealing with mean values of sampling stations, and it is frequently easy to see differences among these values. But this is not enough. One must test the statistical validity of these differences and establish confidence limits. Moreover, it may be desirable to evaluate the degree of similarity of stations and lump those that are closely related in our data terms. Obviously, one is looking for statistically significant changes in benthic communities resulting from dumping. But one may be overconditioned to the term stress and expect that all changes of benthic community structure are deleterious. But such is not the case. In fact, the richness and density of a benthic community may not necessarily decrease under stress even though the original dominant species may be replaced by others. Thus, the interpretive step beyond the establishment of statistical significance of change must be made by experienced marine ecologists, environmental managers, and appropriate EPA and Corps officials.

TREATMENT OF WATER COLUMN DATA

SALINITY

Salinity is the total amount of solid material in grams contained in one kilogram of seawater when all carbonate has been converted to oxide, the bromine and iodine replaced by chlorine, and all the organic matter oxidized. In actual practice the above procedures are not followed. Probes that measure in situ electrical conductivity are in common use today. However, a standard laboratory method for chemically determining salinity is used to calibrate the in situ probes. This procedure is based upon the observation that even when the total concentration of salt varies widely, the relative proportions of the major constituents remain constant. Hence, it is possible to determine salinity by measuring only one major constituent, which is ordinarily chlorine. This chlorinity is determined by titrating a seawater sample with silver nitrate using a potassium chromate indicator. Then salinity is calculated according to the relation:

$$S \text{ (ppt)} = 0.030 + 1.8050 \text{ Chlorinity (ppt)}$$

In the open ocean surface salinity may range from 33 ppt to 37 ppt. But near shore, where most dredged material disposal sites are located, salinities are usually considerably lower than this as a result of river or other land runoff. Ordinarily, salinity increases with depth along a smooth curve (Figure 24, B), but in the vicinity of rivers there may be a sharp halocline in which salinity increases abruptly below the overriding fresh water (Figure 24, A). Such a situation may affect the dispersion of the finer parts of dredged material after discharge. Also, this situation creates a very stable water column in which the passage of oxygen gas into lower layers will be curtailed.

Salinity is best presented as a plot against depth, as shown in Figure 24. Studies done at disposal sites that are affected by substantial

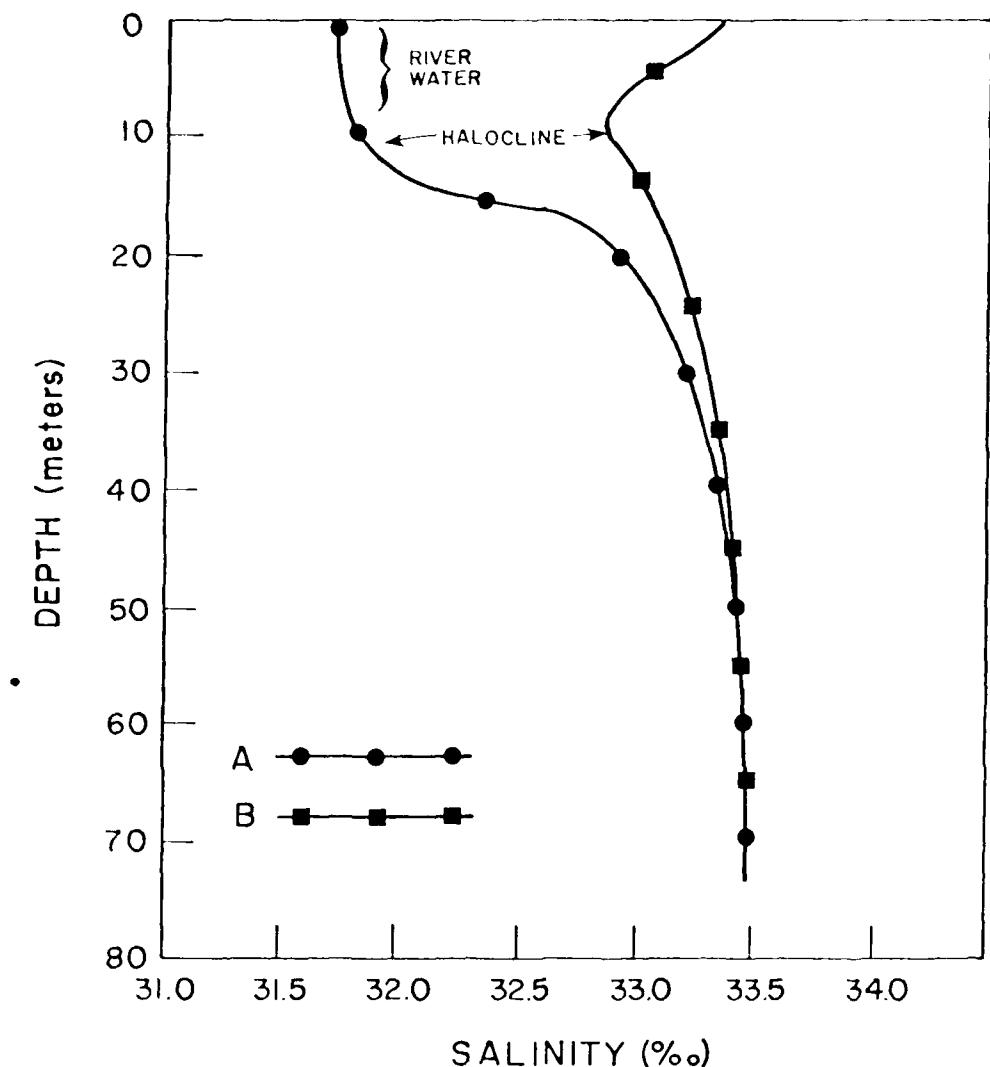


Figure 24. Salinity-depth structure of two imaginary water columns. River water overrides saline water in A, while curve B has a very high salinity water on the surface, possibly as a result of evaporation

river flow should include sufficient STD profiles in and around the site to document the salinity and other differences.

TEMPERATURE

Temperature and salinity, acting separately and together, are the principal factors determining the specific distributional patterns of marine organisms. Ocean temperatures range from a high of approximately 35°C to a low of -2°C. Most of the water in the ocean is at low temperatures between 2° and 6°C. Unlike the atmosphere, which is heated from the bottom adjacent to earth, the ocean is primarily heated from the surface. Hence, the surface layer stores a great deal of thermal energy from the sun. Since light is quickly scattered and absorbed by seawater, only a thin layer is effectively heated. Thus, as the temperature probe is slowly lowered into the water, a point will be reached where the temperature begins to drop rapidly. This layer is called the thermocline (Figure 25). There are two types of thermoclines: the seasonal thermocline, which is shallow and a phenomenon of summer heating, and the permanent thermocline (Figure 25), which lies at a depth of about 200 m, well below the depth of most dredged material disposal sites.

When a thermocline also marks a rapid change in density with depth (a pycnocline), it may be called a thermo-pycnocline. It is a real barrier to mixing of waters above and below the cline, and it also can be a layer of accumulation of living and dying plankton, detritus, fine sediment, and other materials. These effects of the thermo-pycnocline are accentuated where the surface layer has low salinity. In such places one should very carefully measure the dissolved oxygen (DO) near the bottom, since there will be very little mixing with surface water where DO enters the system.

The temperature-depth structure should be presented graphically, much as in Figure 25.

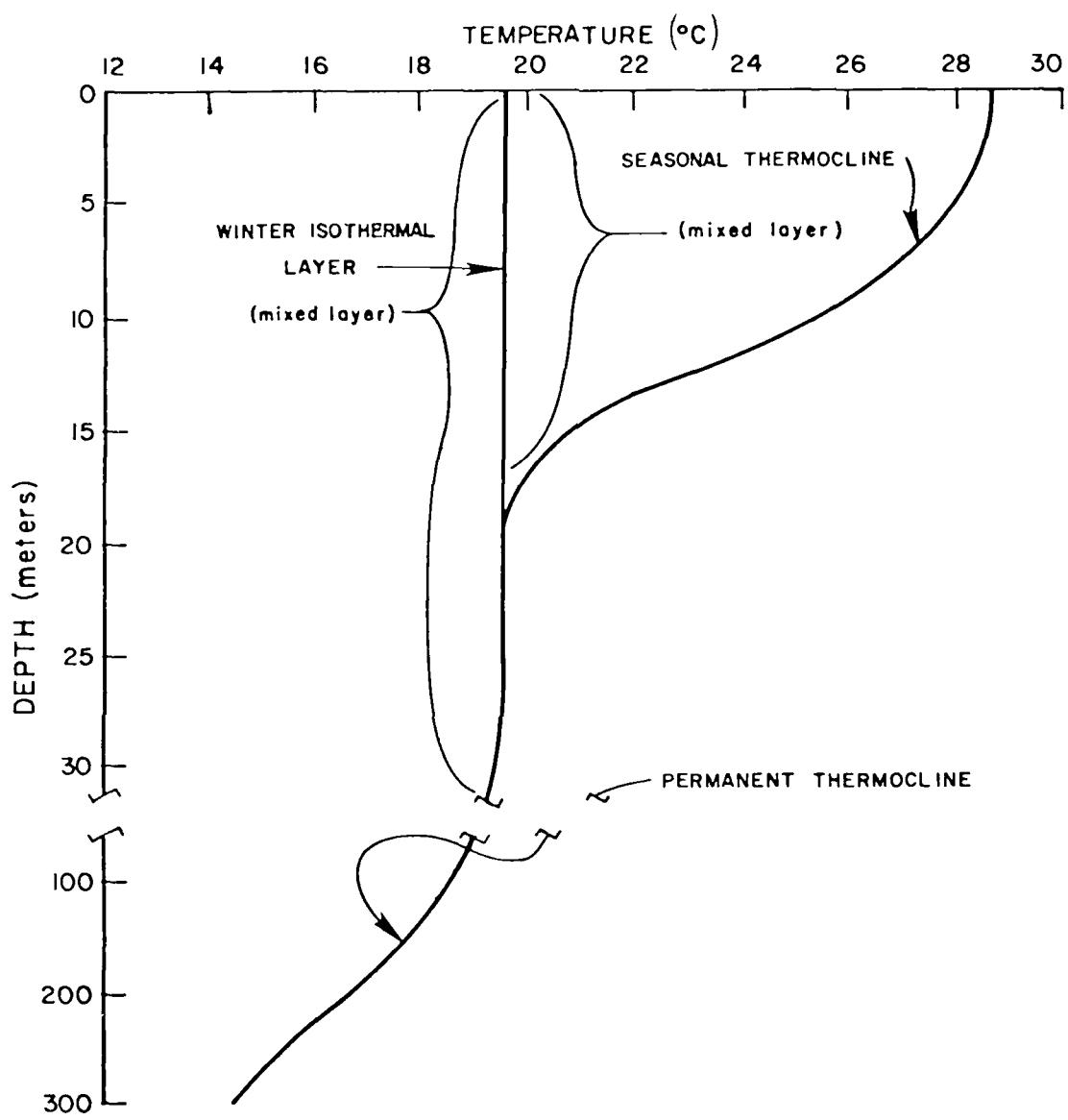


Figure 25. Temperature-depth structure showing the thickness of the mixed layer under control of a seasonal thermocline and its absence. Note position of the permanent thermocline

TEMPERATURE-SALINITY RELATIONSHIPS

There are some advantages in diagramming temperature-salinity (T-S) relationships in an area of complicated water mass origin. Ordinarily, however, dredged material disposal sites are too shallow to permit effective use of this technique to identify water masses. Below the surface layer (upper 100 m) there are characteristic relationships between temperature and salinity which remain virtually constant at a single location. This develops from the fact that below the surface there is no significant process by which either salinity or temperature is changed except by mixing. Near the surface, evaporation or rainfall may change salinity, while temperature may be changed by insolation, radiation, etc. Thus, a water mass picks up its original set of characteristics at the surface, but at depth its T-S characteristics can only be changed by mixing with other waters of different characteristics.

After its formation, a water mass spreads at a level determined by its density relative to the vertical density of the water column. The different water masses occurring in a given water column can thus be revealed by a graph showing changes in density. In practice, however, since density is mainly a function of temperature and salinity and the latter parameters are more easily measurable, a plotting of temperature versus salinity (T-S) is used to depict water masses. On a T-S diagram each reversal of the curve denotes a significant change in density and is thus indicative of a distinct water mass. Figure 26 shows two reversible and thus, the presence of two water masses. The core of a water mass, or in the practical sense that portion which has been mixed or diluted the least, is indicated at the reversal point. The temperature-salinity at the reversal point is a tag that can be used as a tracer for that particular water mass.

DISSOLVED OXYGEN

Dissolved oxygen is a parameter of major concern in several geographic

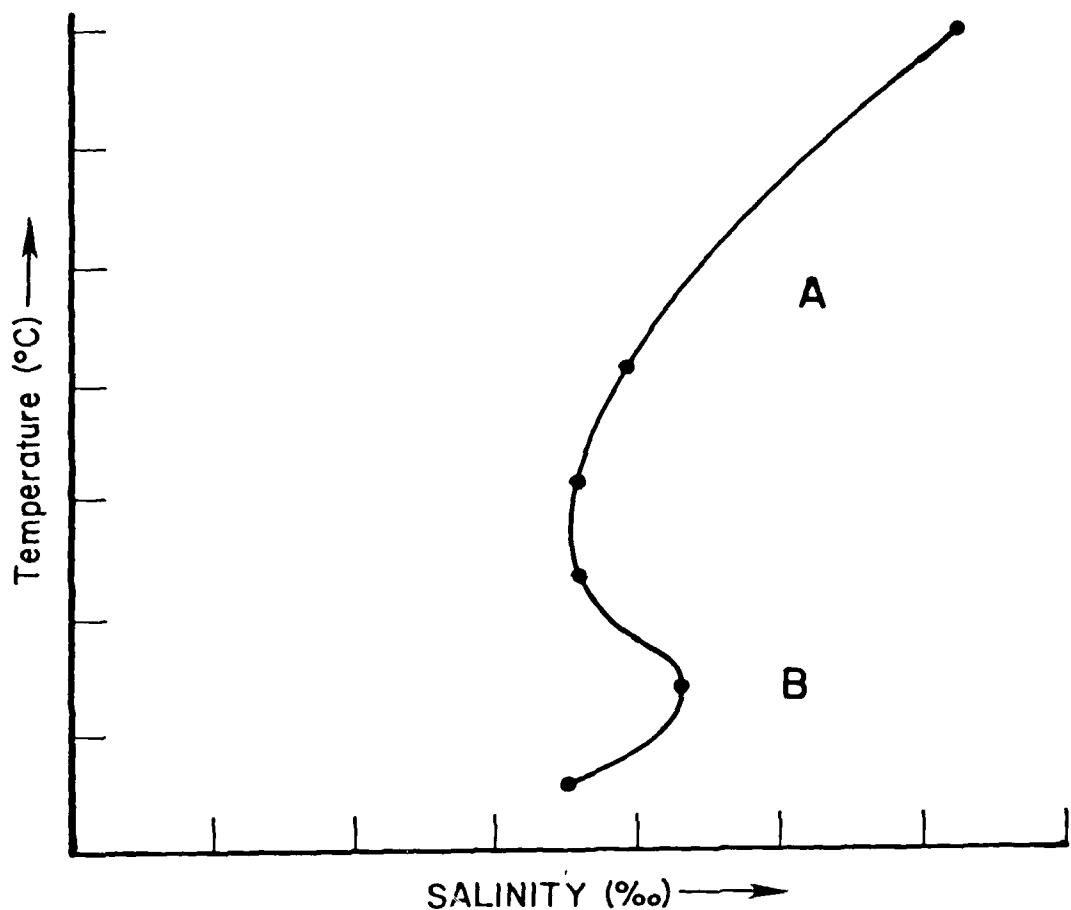


Figure 26. Temperature-salinity diagram from field measurements showing the cores of two different water masses (A and B, which occur at the reversals on the curve)

regions where dredged material disposal sites are located. Specifically, reference is made to the New York Bight and a region west of the Mississippi River Delta where very low levels of dissolved oxygen have been reported in summer in bottom waters. The atmosphere is the main source of oxygen dissolved in seawater. Thus, it is usually near saturation at the surface; indeed, the upper 10-15 meters may be supersaturated, especially in daylight hours, as a result of the photosynthesis of marine plants (e.g., phytoplankton). Low values of dissolved oxygen in seawater in the open ocean usually mean that the water has been away from the surface for a long time. Its original oxygen content has been utilized by animals and the oxidation of organic detritus. However, in local regions heavy oxygen demands may be placed on a parcel of water by, say, the rapid dying of phytoplankton organisms at the height of a bloom which was perhaps triggered by some source of eutrophication.

The concentration of dissolved oxygen in seawater is usually reported in ml/l, which represents the volume in milliliters that the oxygen dissolved in a liter of seawater would occupy at standard temperature (20°C) and pressure (760 mm of Hg). The range of values may go from 0 to 9 ml/l, but most fall between 1.5 and 6.5 ml/l.

When one plots dissolved oxygen values against depth, one of the characteristic aspects of the curve is its minimum point (oxygen minimum) which occurs above depths of 1000 m (Figure 27). As noted above, however, minimal values may be reached in very shallow water as a result of local conditions. Dredged material disposal sites on the shelf may from time to time be bathed with water of low oxygen values that upwells from the continental slope. This can occur as a result of continued blowing of strong offshore winds which push surface waters seaward and permit deeper waters to replace it.

Dissolved oxygen values should be plotted against depth, much as in Figure 27. Values of 4 ml/l or above are very satisfactory, but if

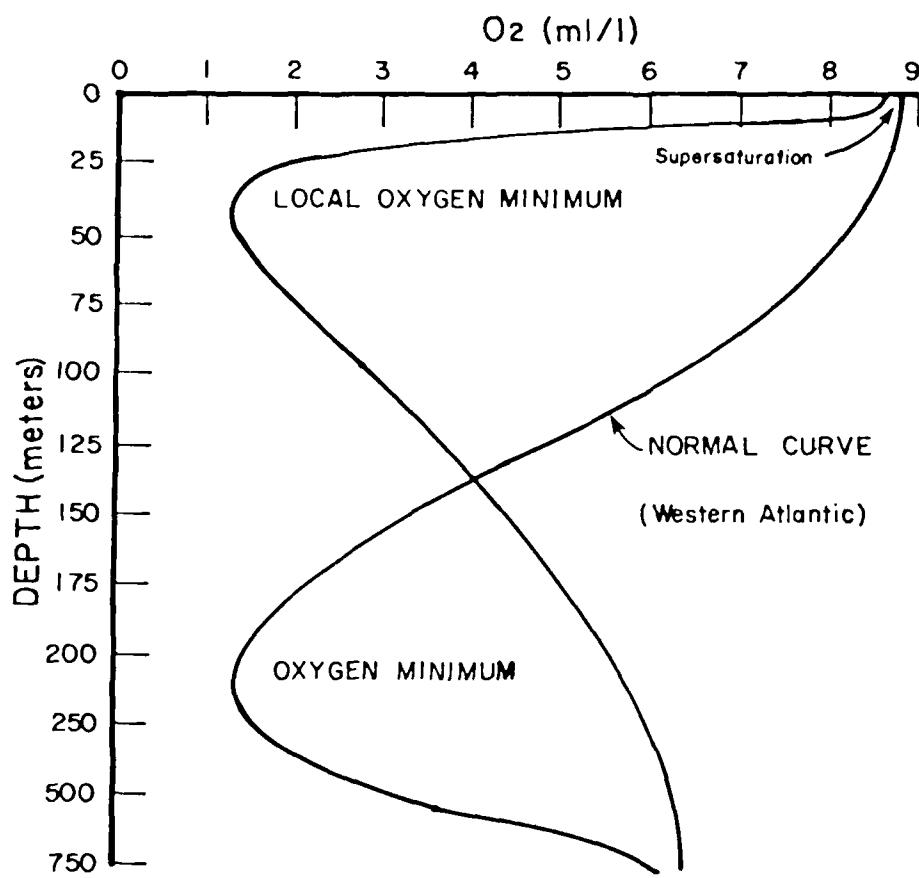


Figure 27. Changes in the concentration of dissolved oxygen with depth. Note particularly the rapid drop toward the oxygen minimum layers

values in bottom water approach 2 ml/l or lower, then additional stations should be added to reveal whether or not the low oxygen water is local at the site or is coming from the contiguous area.

PRESENTATION OF OTHER WATER COLUMN PARAMETERS

Data obtained from the water column for such parameters as trace metals, chlorinated hydrocarbons, high molecular weight hydrocarbons, and total suspended solids are probably best presented in tabular form. If a sufficient number of samples are available, the data should be subjected to the statistical treatment suggested for the benthic biota in a later section of this chapter.

TREATMENT OF DATA FROM THE BOTTOM ENVIRONMENT

Information gained during the ocean survey from the benthic environment is important to completion of site characterization and it is critical to the establishment of a monitoring effort and to evaluation of impacts of the disposal of dredged material.

ANALYSIS OF SEDIMENT DATA

The data derived from grain size analysis can be plotted in several useful ways. Various sediments may have different preferred statistical or graphical evaluative procedures and the literature may help decide which is best for a particular region of the country. However, all of the conventional methods use grain size on the horizontal scale in either phi units or millimeters and percentage frequency as the vertical scale. If using millimeters, plots should be developed on logarithmic base paper. The preferred method, however, is the phi unit plot, which is done on arithmetic base paper, as shown by the two examples of cumulative curves in Figures 28 and 29.

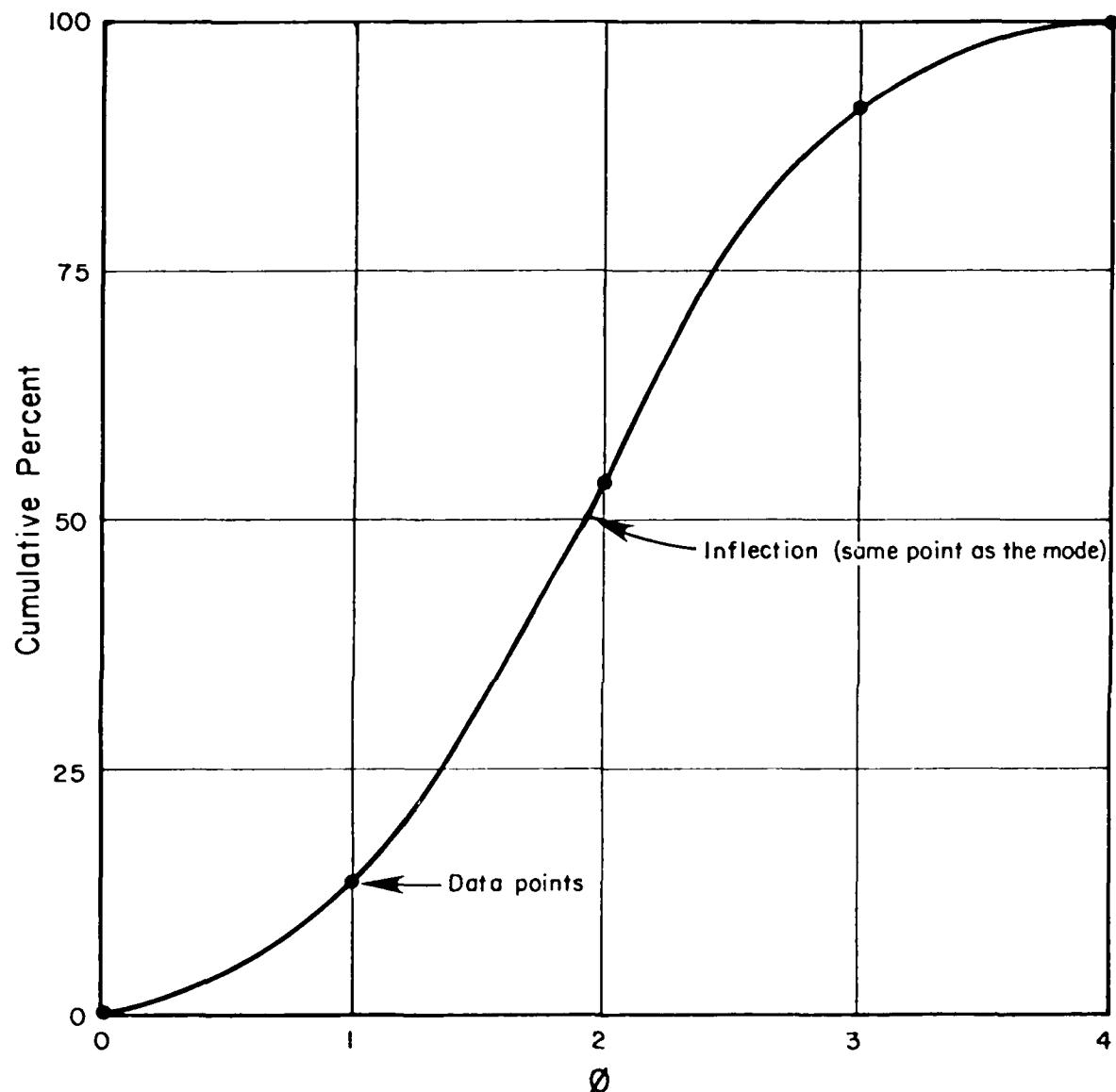


Figure 28. Cumulative curve, arithmetic ordinate

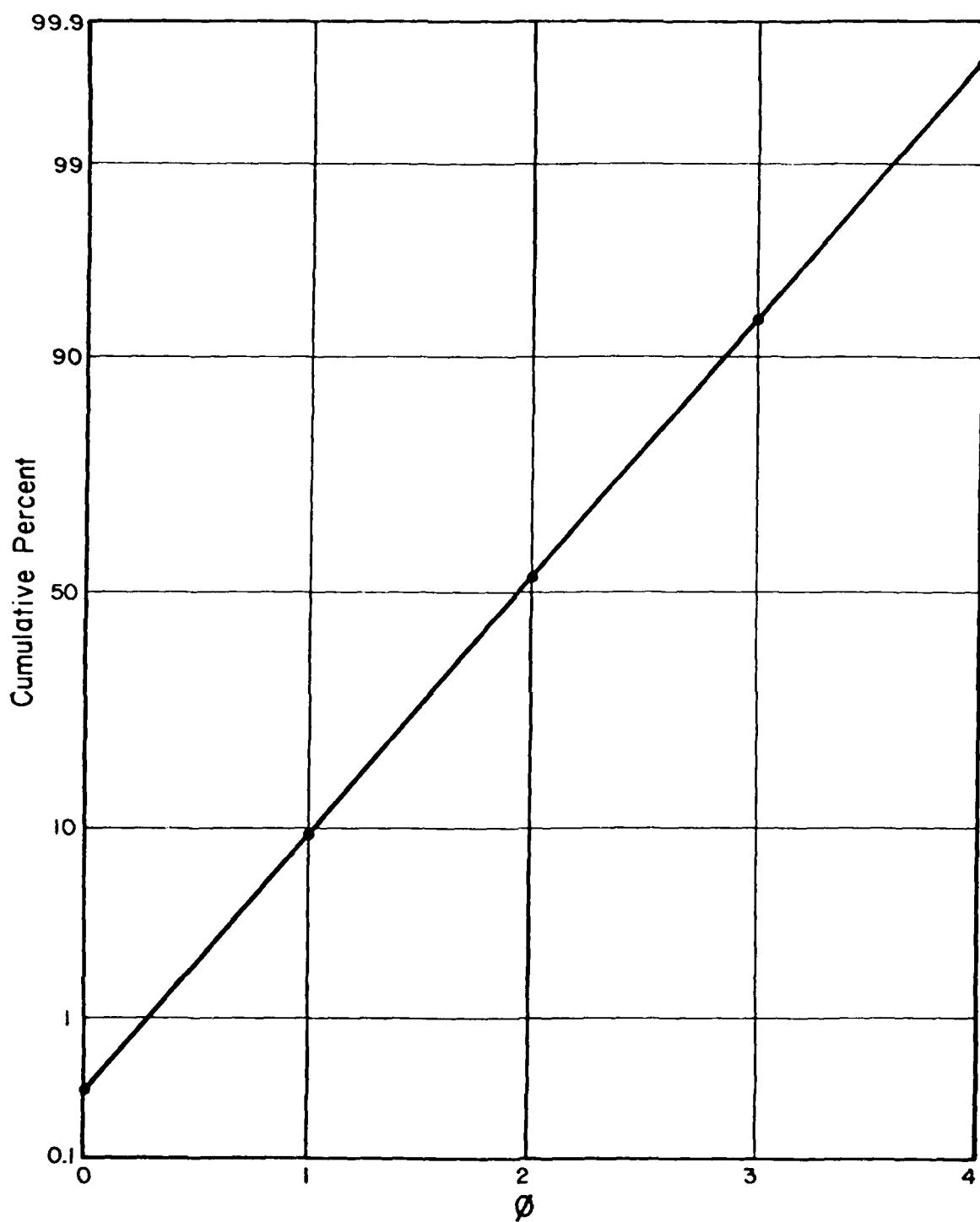


Figure 29. Cumulative curve, probability ordinate.

Cumulative Curve - Arithmetic Ordinate

The cumulative curve plotted against an arithmetic ordinate is commonly used. The ordinate (vertical) is arithmetic running from 0 to 100%, while the abscissa in phi units begins with the small units (coarse material) to the left and moves toward finer materials (large phi units) to the right (Figure 28). It is now possible to plot the cumulative percentages of the sediment on this graphic preparation. For example, if 20% of the sediment sample is coarser than 2 phi, a point is placed on ordinate 20 and abscissa 2. After all data points are entered, a line is drawn through them to form a more or less S-shaped curve. It should be based on one-phi analysis or sieving (Folk 1974).

Cumulative Curve - Probability Ordinate

The cumulative curve plotted against a probability ordinate (on standard probability-90 paper) permits one to read off statistical parameters with greater accuracy since it normally plots as a straight line (Figure 29). The same phi units are used on the abscissa, but the ordinate is stretched out at the ends (curves of the S-curve) and condensed or shortened in the middle, resulting in a straight line (or nearly so under most conditions). The position of the line reflects the average particle size and its slope depends upon the degree of sorting.

Some survey investigators may wish to construct a cumulative probability curve first and then transcribe the easily read data points on arithmetic base paper.

Graphic Mean

There are various statistical parameters that can be read from the plotted curves. Among them are the mode, median, and mean. The mode

is the most common grain diameter; it is not frequently used. The median is not frequently used, but it indicates the point at which half of the particles by weight are coarser than the median and half are finer. Of greater usefulness is the graphic mean, which gives one an overview of particular sizes. It is calculated as:

$$\text{Graphic mean} = \frac{\phi_{16} + \phi_{50} + \phi_{84}}{3}$$

Mode

The mode is the grain size of the sample that has the highest population or occurs most frequently. It is best to determine the mode by trial and error. To do this one must inspect the cumulative probability curve, pick where the mode ought to be, and then measure the percentage of the sample that falls with the grain size from 0.25ϕ unit coarser than that point to 0.25ϕ unit finer than that point. Then, one must move over 0.1ϕ unit to a new potential mode and measure the percentage of the sample within the 0.5ϕ interval with the new mode as the center. This process is continued until the highest percentage is found, which is the model diameter.

If a sediment sample has more than one mode, one should not be confused. This parameter can be valuable in determining transport; ordinarily it remains fairly constant.

Inclusive Graphic Standard Deviation

This is the best available method for measuring the uniformity or sorting of sediments. It is derived from the cumulative curve as:

$$\text{Inc. Graphic St. Deviation} = \sqrt{\frac{\phi_{84} - \phi_{16}}{4} + \frac{\phi_{95} - \phi_{50}}{6.6}}$$

Well-sorted sediments should have a value of 0.35 ϕ , whereas poorly sorted sediments would be 4.0 ϕ or more.

Inclusive Graphic Skewness - Optional

This is a good measure of the degree of asymmetry of the curve of grain size distribution:

$$\text{Incl. Graphic Skewness} = \frac{\phi_{16} + \phi_{84} - 2\phi_{50}}{2(\phi_{84} - \phi_{16})} + \frac{\phi_5 + \phi_{95} - 2\phi_{50}}{2(\phi_{95} - \phi_5)}$$

The skewness term is either positive or negative. Those samples with abnormal fine material (curve has a tail to the right) have positive skewness, whereas those with excess coarse material (tail to left) have negative skewness.

Kurtosis or Peakedness - Optional

If the curve of the particular sediment sample under study at the moment is a straight line on the probability graph, its constituents follow a normal curve. This can be checked by noting that if it is a normal curve, the following phi diameter intervals have the following relationship:

$$\text{Graphic Kurtosis (GK)} = \frac{\phi_{95} - \phi_5}{2.44 (\phi_{75} - \phi_{25})}$$

For normal curves GK = 1.00. If the curve is very peaked (leptokurtic), it will have a GK over 1.00. This means it is better sorted, i.e., it has a better dispersion. When the tails of the curve have a small spread, they are said to be platykurtic and can be expected to have a GK under 1.00. Most sediments have GKs at some point between 0.85 and 1.0.

Plot of Station Sediments on Triangular Diagram

In order to depict the relationships between the mean sediment type found at sampling stations, one may utilize plots on a triangular diagram, as shown in Figure 30. The station locations can be plotted knowing any two relationships, e.g. the percentages of sand:silt, sand:clay, silt:clay. The example given in Figure 30 indicates that the material being dumped is finer grained than that at either the upstream or downstream stations. It would appear that the upstream stations, which have higher percentages of sand, represent the indigenous mean surficial sediment type, and that the downstream stations have acquired a fine component as a result of dumping and transport of clay-size grains.

Chemical Pollutants in the Sediments

Data from chemical pollutants contained in the surficial sediments should be presented in tabular form and also plotted on a simple line drawing of the disposal site and contiguous areas, much as in Figure 31. Data from the seasonal samples as well as from monitoring should be plotted on the same map in order to portray any trends that are present.

ANALYSIS OF DATA FROM THE BENTHIC BIOTA

WHAT THE SAMPLE REPRESENTS

Effective sampling of populations of benthic organisms is very difficult to achieve. The range of size from a few microns to a meter or more and of mobility from languid burrowers to fast-moving crabs and demersal fishes is such that no single sampling device can be expected to work equally well for all ecological types. Even when one is sampling for a single type, say, the macrofaunal species that live within the sediments, the dispersion of individuals is likely to be clumped or

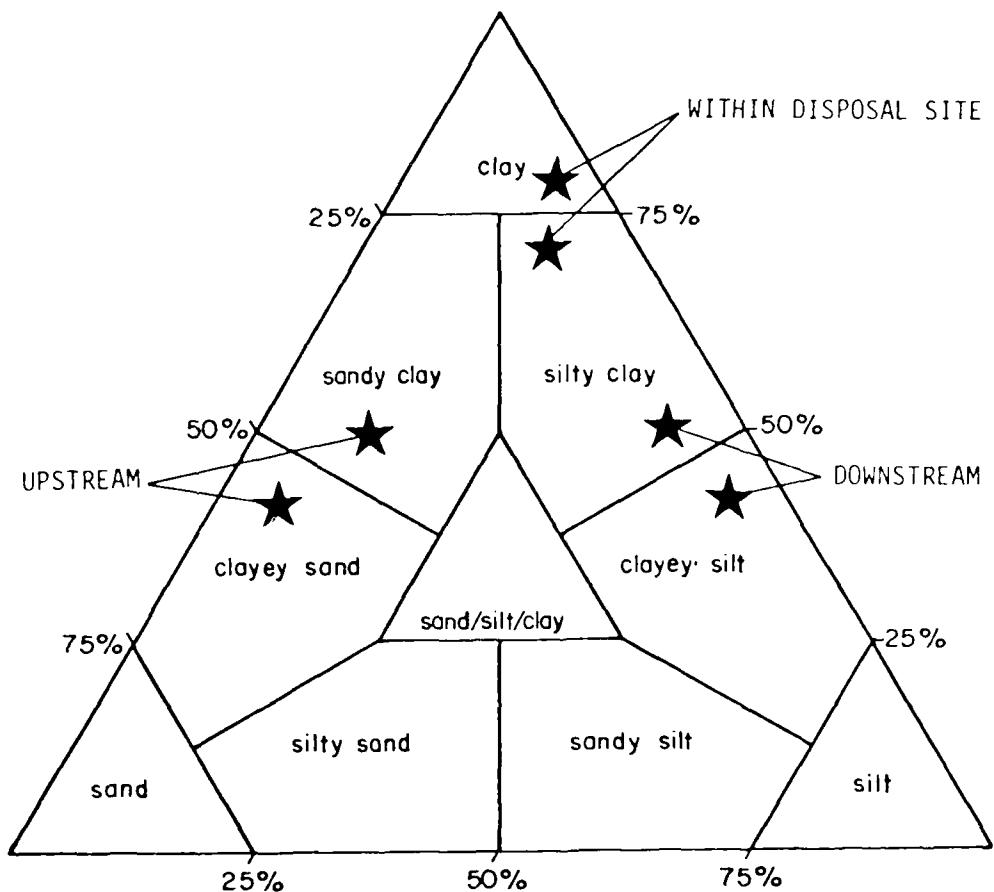


Figure 30. Surficial sediment analysis (top 5 cm) at the six stations (stars) plotted on a standard sediment-type triangle. Two parameters are necessary for plotting the position

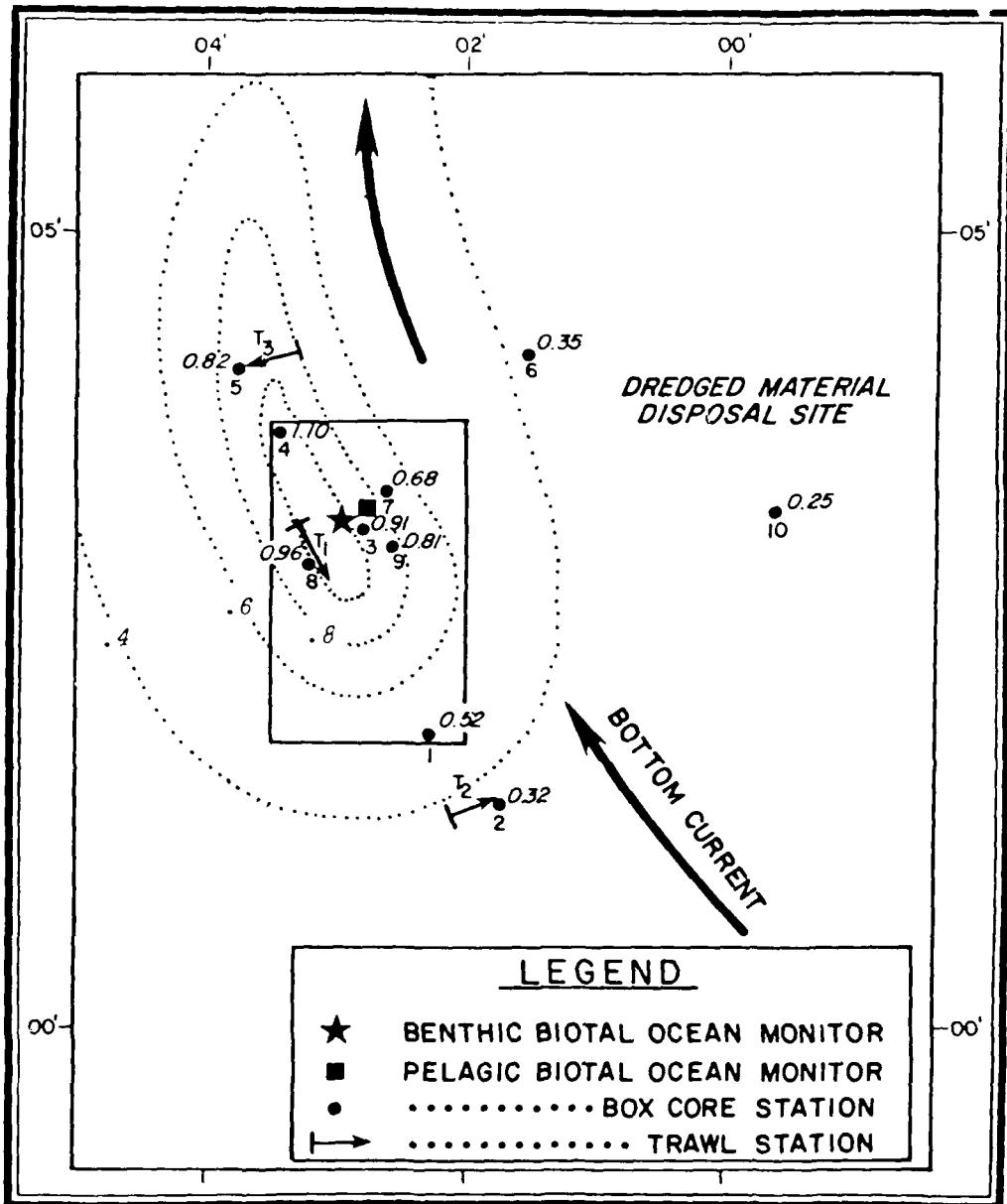


Figure 31. Example of data presentation for a chemical pollutant collected with a box corer. Hypothetical values for cadmium levels (in ppm) are shown in italics

patchy rather than random or even. As a result some attempts to sample will yield negative results, making it necessary to take a series of replicates at a station if one is to obtain a representative sample. The term representative sample in this context means the real populations from which the samples were taken; hence, a sufficient number of individual samples must be taken to permit use of sample statistics to estimate real population statistics. Thus, it may take a series of individual samples to give the composite representative sample.

POPULATION STATISTICS

In a given region all of the individuals of a species in which there is a critical interest comprise the population of that species. Obviously, this is an imaginative abstraction because what space the species occupies is not known; hence, one seeks to determine its average density, i.e., the number of individuals per some unit of area (e.g., per square meter). If only a single sample is taken, the ability to judge how representative the sample is is limited. But when several replicates are taken at each of several stations, certain statistical parameters can be employed to evaluate the reliability of the estimates. A simple but very valuable first step is to calculate the arithmetic mean, which is the sum of all the individuals collected divided by the number of samples. Knowing the area of the sampler, one can multiply to come up with the average density per square meter. The mean also represents the center of the observations in the samples, and thus it is the starting point of the analysis of the spread of values. The first step here is to observe the range of the number of individuals taken per sample from highest to lowest. When the population of a species is clumped, the range will usually be large. Thus, if several values are available, it is advisable to calculate the variance and standard deviation, which weight each sample value by its distance from the mean (center). The variance is the sum of squared deviations from the mean divided by the number of samples less one (degrees of

freedom). The standard deviation is derived by taking the square root of the variance. For a discussion, consult a standard text book of statistics such as Biometry (Sokal and Rohlf 1969).

COMMUNITY STATISTICS

Thus far only the populations of the species have been considered. Seldom will the ocean surveys be limited to interest in single species. Rather, researchers want to consider groups of species, which may loosely be called communities. For this study's purposes, then, a community may be considered as being comprised of the populations of several species. One is also interested in species richness and how individuals are distributed among the component species (equitability). Also, one may wish to know to what extent the samples represent all of the species of a community, and it may be useful to determine how closely total samples are related and to place closely related stations in discrete groups. Since communities are comprised of individual species, some of the statistics developed for populations can be used, but the more complex aspects of community structure will require different statistical techniques. Accordingly, let us start first with population statistics and apply it to the macroinfauna.

PRESENTATION OF POPULATION DATA ON THE MACROINFAUNA

The major components of the macroinfauna, which live in the sediments and are retained on a 0.5-mm sieve, are generally polychaete annelid worms, bivalve mollusks, and various crustaceans such as amphipods and isopods. The most appropriate devices for sampling the macroinfauna are either a box corer (see Figure 18, p. 140) of appropriate size (say, taking a 30- by 30-cm area of the bottom sediments) or a Smith-McIntyre grab. Much of the population data derived for the macroinfauna can be presented very effectively in tabular form (Table 33).

Table 33
Tabulation of Some Population Values for Five Macrofaunal Species

Species	Individual (x)					95% Confidence Limits of Mean	Standard Deviation	Coefficient of Dispersion	Species Rank	Percent of Total	Cumulative Percent
	1	2	3	4	5						
Polychaete species A	140	110	80	40	105	475	95	48.6 - 141.4	37.42	14.74	1 57 57
Polychaete species B	65	75	50	35	60	285	57	38.1 - 75.9	15.25	4.08	2 34 91
Bivalve species 1	15	12	8	6	45	9	3.5	14.6	4.47	2.22	3 5 96
Amphipod species A	10	4	3	2	6	25	5	0.2 - 9.8	3.87	3.00	4 3 99
Bivalve species 2	3	0	1	0	1	5	1	0.0 - 1.5	1.20	1.50	5 1 100
TOTALS	233	201	142	81	178	835	167				
Number of Species	5	4	5	4	5						

The following calculations are based on data for Polychaete sp. A in Table 33. Five replicate box corer samples have been taken of the macroinfauna at a particular station. After sieving the sediment through a nest of sieves, the smallest mesh of which is 0.5 mm, the retained organisms are sorted and the number of individuals of each selected species enumerated. After tabulating the data, a useful statistic to calculate is the standard deviation (a measure of dispersion) as is shown stepwise below:

- a. First find the mean $\bar{x} = \frac{\sum x}{n} = \frac{475}{5} = 95$
- b. Find the deviation of each sample from the mean $x = X - \bar{x} = +45, +15, -15, -55, +10$
- c. Square each deviation $x^2 = (X - \bar{x})^2 = 2025$
225
225
3025
100
- d. Find the sum of the squared deviations (sum of squares) $\Sigma x^2 = \sum (X - \bar{x})^2 = 5600$
- e. Divide the sum of squares by the degrees of freedom $(n - 1) = \text{variance}$ $\sigma^2 = \frac{\sum x^2}{n - 1} = \frac{5600}{4} = 1400$
- f. Extract the square root to find the standard deviation $\sigma = \sqrt{\frac{\sum x^2}{n - 1}} = 37.42$

Based on the nature of the normal curve, 68% of the samples should have values falling between plus or minus one standard deviation from the mean, which in this case is:

$$95 + 37.42 = 132.42, \text{ and}$$

$$95 - 37.42 = 57.58$$

It is usually expected that one will calculate confidence limits of the mean at the 95% level. In other words, this means that one can be 95% sure that the true population mean lies between the confidence

limits. This parameter is calculated from the standard deviation, the number of samples, and the value of t which can be found in any statistics text (see Table 35, page 233).

$$\% \text{ Conf. Limit} = \frac{t \sigma}{\sqrt{n}} = \frac{2.78 \times 37.42}{2.24} = \frac{104.03}{2.24} = 46.44$$

This means that there is only one chance in twenty that one would be wrong if one assumes the true population mean lies between 141.44 and 48.56. The spread is very large because of the small number of samples and the patchy nature of distribution of Polychaete species A in the sediments. One can always infer that this nonrandom distribution occurs when the variance is substantially larger than the mean (in this case 1400 vs. 95). This can be regularized by calculating another parameter - the coefficient of dispersion.

The coefficient of dispersion (CD) is simply the ratio between the variance and the mean

$$CD = 1400:95 = 14.74$$

Random Distribution: CD = 1
Clumped (patchy): CD = >1
Even: CD = <1

From this it is concluded that the individuals of Polychaete species A with a CD of 14.74 are strongly clumped and possibly have what one might call "contagious" distribution, i.e., that the presence of one individual serves as a strong attractant for another, and the two for yet another, etc.

The above findings regarding the macrofaunal species populations can be applied to a monitoring program in the following ways. First, the monitoring sampling would be done with the same collecting gear, at the same stations, and as near as feasible to the same period of year

as the baseline survey. Then one would note:

- a. changes, if any, in species richness, recording particularly absences of species and the appearance of species that were previously not present
- b. whether or not the predominant species have changed, i.e., whether the structure of the community shifted
- c. then it should be noted whether or not the mean values for each species and the sum of the means for the predominant species are the same or different, and the difference should be tested statistically for significance

Test of the Significance of the Difference Between Two Means

Suppose the results of sampling Polychaete sp. A during the baseline and monitoring surveys are compared for the significance of the difference. This can be done by ANOVA (analysis of variance for two groups) or by the t-test of the differences between two means. Since many investigators are more familiar with it than with ANOVA, this study shall utilize the t-test. Perhaps it should be added that they are equivalent mathematically.

Polychaete sp. A - Number in Core

<u>Box Core Number</u>	<u>Baseline Survey</u>	<u>Monitoring Survey</u>
1	140	110
2	110	105
3	80	45
4	40	50
5	105	115
TOTALS	475	425
MEAN (\bar{x})	95	85
STANDARD DEVIATION	37.4	34.4
COEFFICIENT OF DISPERSION	14.74	13.97

The baseline survey at the test station has a mean number of individuals of Polychaete sp. A of 95 with a standard deviation of 37.4 individuals,

and five samples from the same station during the monitoring survey yielded a mean number of individuals of Polychaete sp. A of 85 with a standard deviation of 34.4 individuals. It is anticipated that using the t-test will determine the significance of the observed difference. But before calculation of t, it is necessary to ascertain if the variances of the two sets of data are homogeneous. For this purpose, one may employ Cochran's test for the homogeneity of variances in which the test C is solved as the ratio of the largest variance to the sum of all variances.

$$C = \frac{\sigma^2_{\max}}{\sum \sigma^2} = \frac{1400}{2587.5} = 0.54$$

This value of C is interpreted by comparing it to the table of C values (Table 34). In the table, k is the number of sample variances summed in the denominator and v is one less than the number of samples contributing to each variance. The tabulated value of C is 0.7679. Since the calculated C-value (0.54) is smaller than the tabular C-value, the calculated value is not significant at the 95 percent confidence level; and the variances may be considered homogeneous. If the calculated C-value is larger than the tabulated, the variances are not homogeneous. In this event the data must be transformed in order to equalize the variances. There are three common transformations but the most frequently used is the logarithmic transformation using common logarithms log (x); if zero counts are involved, log (x + 1) is used. The one finds the C-value of the transformed data. If the variances are now homogeneous, the transformed data are used in deriving the t-test or analysis of variance to test significance. To report these data, the means are transformed back to the linear scale by finding their antilogarithms.

Student t-test

Since the variances between the baseline and monitoring surveys were

Table 34

Critical Values for Cochran's Test*

Values given are for the statistic $(\text{largest } s^2)/(\bar{s}^2)$, where each of the k values of s^2 has v degrees of freedom.

		PERCENTILE .95												
		1	2	3	4	5	6	7	8	9	10	16	36	144
$\frac{k}{v}$		0.9985	0.9750	0.9392	0.9057	0.8772	0.8534	0.8332	0.8159	0.8010	0.7880	0.7311	0.6802	0.5813
3		0.9669	0.8709	0.7977	0.7457	0.7071	0.6771	0.6530	0.6333	0.6167	0.6025	0.5466	0.4748	0.5000
4		0.9065	0.7679	0.6841	0.6287	0.5895	0.5598	0.5365	0.5175	0.5017	0.4884	0.4398	0.3933	0.3333
5		0.8412	0.6838	0.5981	0.5441	0.5085	0.4783	0.4564	0.4387	0.4241	0.4118	0.3845	0.3060	0.2000
6		0.7808	0.6161	0.5321	0.4803	0.4447	0.4184	0.3980	0.3817	0.3682	0.3568	0.3135	0.2012	0.2513
7		0.7271	0.5612	0.4800	0.4307	0.3974	0.3726	0.3535	0.3384	0.3250	0.3164	0.2756	0.2278	0.1667
8		0.6798	0.5157	0.4377	0.3910	0.3555	0.3362	0.3185	0.3043	0.2926	0.2820	0.2462	0.2022	0.1429
9		0.6385	0.4775	0.4027	0.3584	0.3295	0.3067	0.2901	0.2768	0.2650	0.2568	0.2225	0.1820	0.1250
10		0.6020	0.4450	0.3733	0.3311	0.3029	0.2823	0.2666	0.2541	0.2439	0.2353	0.2032	0.1655	0.1111
12		0.5410	0.3924	0.3264	0.2880	0.2624	0.2439	0.2299	0.2187	0.2098	0.2020	0.1737	0.1403	0.1000
15		0.4709	0.3346	0.2758	0.2419	0.2195	0.2034	0.1911	0.1815	0.1730	0.1671	0.1429	0.1144	0.0833
20		0.3894	0.2705	0.2205	0.1921	0.1735	0.1602	0.1501	0.1422	0.1357	0.1303	0.1108	0.0870	0.0607
24		0.3434	0.2354	0.1907	0.1656	0.1493	0.1374	0.1286	0.1216	0.1160	0.1113	0.0942	0.0743	0.0567
30		0.2929	0.1980	0.1593	0.1377	0.1237	0.1137	0.1061	0.1002	0.0958	0.0921	0.0771	0.0604	0.0457
40		0.2370	0.1576	0.1259	0.1082	0.0908	0.0887	0.0827	0.0780	0.0745	0.0713	0.0595	0.0462	0.0347
60		0.1737	0.1131	0.0995	0.0765	0.0682	0.0623	0.0583	0.0552	0.0520	0.0497	0.0411	0.0316	0.0234
120		0.0998	0.0632	0.0495	0.0419	0.0371	0.0337	0.0312	0.0292	0.0279	0.0256	0.0218	0.0165	0.0167
∞		0	0	0	0	0	0	0	0	0	0	0	0.0020	0.0032

* By permission from C. Eisenhart, M. W. Hastay, W. A. Wallis, *Techniques of Statistical Analysis*, chap. 15. McGraw-Hill Book Company, New York, 1947.

found to be homogeneous, one is now ready to test significance of mean differences with the t-test (other tests of significance may be used).

Box Core Replicates	Population Numbers of Polychaete sp. A	
	Baseline Survey (\bar{x})	Monitoring Survey (\bar{x})
1	140	110
2	110	105
3	80	45
4	40	50
5	105	115
$\Sigma \bar{x}$	475	425
$\bar{x} = \frac{\Sigma \bar{x}}{N}$	95	85
Sum of squares SS = $\sum (x - \bar{x})^2$	5600	4750
Variance $\sigma^2 = \frac{SS}{n - 1}$	1400	1187.50
$t = \frac{\bar{x}_b - \bar{x}_m}{\sqrt{\sigma_b^2 + \sigma_m^2}}$	$= \frac{95 - 85}{\sqrt{1400 + 1187.50}}$	$= \frac{10}{\sqrt{517.50}} = 0.44$

Comparing the $t = 0.44$ with the tabulated value with 8 df and $+0.05$, a value of 2.306 is found (Table 35). Since the calculated t-value is less than the tabulated, the difference between the means is not significant. Thus, it can be concluded that the population of Polychaete sp. A has not changed significantly in the interval between baseline and monitoring surveys at the collecting station involved.

Analysis of Variance - ANOVA

The t-test of significance is satisfactory for any situation that involves only two groups and a test of the difference between their means. When, however, testing of three or more groups is desired, analysis of variance or ANOVA is used. The t-test could still be used with three groups to evaluate the difference between the means by comparing 1 and 2, 2 and 3, and 1 and 3. The ANOVA permits testing of differences among all of the means at the same time and its test of significance is the so-called F-distribution.

Table 35

Distribution of t^*

Degrees of Freedom	Probability of a Larger Value, Sign Ignored								
	0.500	0.400	0.200	0.100	0.050	0.025	0.010	0.005	0.001
1	1.000	1.376	3.078	6.314	12.706	25.452	63.657	14.089	31.598
2	.816	1.061	1.886	2.920	4.303	6.205	9.925	14.089	31.598
3	.765	.978	1.638	2.353	3.182	4.176	5.841	7.453	12.941
4	.741	.941	1.533	2.132	2.776	3.495	4.604	5.598	8.610
5	.727	.920	1.476	2.015	2.571	3.163	4.032	4.773	6.859
6	.718	.906	1.440	1.943	2.447	2.969	3.707	4.317	5.959
7	.711	.896	1.415	1.895	2.365	2.841	3.499	4.029	5.405
8	.706	.889	1.397	1.860	2.306	2.752	3.355	3.832	5.041
9	.703	.883	1.383	1.833	2.262	2.685	3.250	3.690	4.781
10	.700	.879	1.372	1.812	2.228	2.634	3.169	3.581	4.587
11	.697	.876	1.363	1.796	2.201	2.593	3.106	3.497	4.437
12	.695	.873	1.356	1.782	2.179	2.560	3.055	3.428	4.318
13	.694	.870	1.350	1.771	2.160	2.533	3.012	3.372	4.221
14	.692	.868	1.345	1.761	2.145	2.510	2.977	3.326	4.140
15	.691	.866	1.341	1.753	2.131	2.490	2.947	3.286	4.073
16	.690	.865	1.337	1.746	2.120	2.473	2.921	3.252	4.015
17	.689	.863	1.333	1.740	2.110	2.458	2.898	3.222	3.965
18	.688	.862	1.330	1.734	2.101	2.445	2.878	3.197	3.922
19	.688	.861	1.328	1.729	2.093	2.433	2.861	3.174	3.883
20	.687	.860	1.325	1.725	2.086	2.423	2.845	3.153	3.850
21	.686	.859	1.323	1.721	2.080	2.414	2.831	3.135	3.819
22	.686	.858	1.321	1.717	2.074	2.406	2.819	3.119	3.792
23	.685	.858	1.319	1.714	2.069	2.398	2.807	3.104	3.767
24	.685	.857	1.318	1.711	2.064	2.391	2.797	3.090	3.745
25	.684	.856	1.316	1.708	2.060	2.385	2.787	3.078	3.725
26	.684	.856	1.315	1.706	2.056	2.379	2.779	3.067	3.707
27	.684	.855	1.314	1.703	2.052	2.373	2.771	3.056	3.690
28	.683	.855	1.313	1.701	2.048	2.368	2.763	3.047	3.674
29	.683	.854	1.311	1.699	2.045	2.364	2.756	3.038	3.659
30	.683	.854	1.310	1.697	2.042	2.360	2.750	3.030	3.646
35	.682	.852	1.306	1.690	2.030	2.342	2.724	2.996	3.591
40	.681	.851	1.303	1.684	2.021	2.329	2.704	2.971	3.551
45	.680	.850	1.301	1.680	2.014	2.319	2.690	2.952	3.520
50	.680	.849	1.299	1.676	2.008	2.310	2.678	2.937	3.496
55	.679	.849	1.297	1.673	2.004	2.304	2.669	2.925	3.476
60	.679	.848	1.296	1.671	2.000	2.299	2.660	2.915	3.460
70	.678	.847	1.294	1.667	1.994	2.290	2.648	2.899	3.435
80	.678	.847	1.293	1.665	1.989	2.284	2.638	2.887	3.416
90	.678	.846	1.291	1.662	1.986	2.279	2.631	2.878	3.402
100	.677	.846	1.290	1.661	1.982	2.276	2.625	2.871	3.390
120	.677	.845	1.289	1.658	1.980	2.270	2.617	2.860	3.373
∞	.6745	.8416	1.2816	1.6448	1.9600	2.2414	2.5758	2.8070	3.2905

* Parts of this table are reprinted by permission from R. A. Fisher's *Statistical Methods for Research Workers*, published by Oliver and Boyd, Edinburgh (1925-1950); from Maxine Merrington's "Table of Percentage Points of the t -Distribution," *Biometrika*, 32:300 (1942); and from Bernard Ostle's *Statistics in Research*, Iowa State College Press (1954).

Suppose, for example, one wishes to compare the means for a given species from samples taken at the dredged material site, at a downstream site, and upstream of the site. Using Bivalve sp. 1 as the test organism, its population values in five replicate box cores at the three locations are shown in Table 36.

Table 36
Individuals of Bivalve sp. 1 Taken in Five Replicate
Box Cores at Three Stations: Dredged Material Disposal Site,
Downstream Site, and Upstream Site. All Samples = N

	DM DISPOSAL SITE (N1)	DOWNTSTREAM SITE (N2)	UPSTREAM SITE (N3)
Sample (\bar{x})	\bar{x}^2	\bar{x}^2	\bar{x}^2
2	4	4	16
2	4	6	36
3	9	7	49
7	49	9	81
6	36	9	81
20	102	35	263

The basic assumption (called the null hypothesis) is that the three groups of samples are random samples collected from a normally distributed population. Two estimates of the population variance are calculated: a sum of squares based upon variation within the three groups, and a sum of squares based upon the variation between the group means. The two estimates of the population variance may be expected to differ only within the limits of random sampling. The null hypothesis is tested by dividing the larger variance by the smaller variance to get the variance ratio; the 5 and 1 percent points of the variance ratio are called F, the values for which are found in Table 37. If the observed F-value equals or exceeds the table value, the null hypothesis is rejected and it may be concluded that the samples were not drawn from the same common normal population. In this case the populations from which the samples were drawn may differ in terms of means or variances or both. If the variances are about the same, it is the

Table 37

The 5 (Roman Type) and 1 (Boldface Type) Percent Points for the Distribution of F^*

n ₁	n ₂ degrees of freedom (for greater mean square)																								
	1	2	3	4	5	6	7	8	9	10	11	12	14	16	20	24	30	40	50	76	100	200	500	∞	
1	161.200	216.225	230.214	217.239	241.242	243.244	245.246	248.249	250.251	252.253	253.254	254.254	254.254	254.254	254.254	254.254	254.254	254.254	254.254	254.254	254.254	254.254	254.254	254.254	
2	4.952	4.999	5.403	5.625	5.754	5.859	5.928	5.931	6.012	6.056	6.083	6.106	6.142	6.169	6.208	6.234	6.258	6.286	6.304	6.333	6.354	6.353	6.361	6.366	
3	98.49	99.30	99.17	99.25	99.30	99.33	99.33	99.36	99.38	99.39	99.40	99.41	99.42	99.43	99.44	99.45	99.46	99.47	99.48	99.49	99.49	99.49	99.49	99.49	99.50
4	10.13	12.30	13.07	13.17	13.25	13.30	13.30	13.37	13.38	13.39	13.40	13.41	13.42	13.43	13.44	13.45	13.46	13.47	13.48	13.49	13.49	13.49	13.49	13.50	
5	34.12	39.82	42.46	42.77	42.91	42.95	42.98	43.00	43.01	43.02	43.03	43.04	43.05	43.06	43.07	43.08	43.09	43.10	43.11	43.12	43.13	43.14	43.15	43.16	
6	7.71	8.94	6.59	6.39	6.20	6.16	6.14	6.09	6.04	6.00	5.95	5.91	5.87	5.84	5.80	5.77	5.74	5.71	5.67	5.60	5.56	5.53	5.51	5.51	
7	21.20	18.80	16.39	15.98	15.33	15.21	14.98	14.80	14.66	14.54	14.53	14.37	14.24	14.15	14.02	13.93	13.83	13.74	13.69	13.61	13.57	13.53	13.48	13.46	
8	6.61	6.79	5.41	5.10	5.05	4.95	4.88	4.82	4.78	4.74	4.70	4.68	4.64	4.60	4.56	4.52	4.48	4.44	4.42	4.40	4.38	4.37	4.33	4.33	
9	16.26	13.27	12.06	11.39	10.97	10.67	10.43	10.27	10.15	10.05	9.96	9.89	9.77	9.68	9.55	9.47	9.38	9.29	9.24	9.17	9.13	9.07	9.04	9.02	
10	5.99	5.14	4.76	4.53	4.30	4.28	4.21	4.15	4.10	4.06	4.03	4.00	3.96	3.90	3.87	3.84	3.81	3.77	3.75	3.72	3.71	3.69	3.68	3.67	
11	13.74	10.92	9.78	9.15	8.75	8.47	8.26	8.10	7.98	7.87	7.79	7.72	7.66	7.52	7.39	7.31	7.23	7.14	7.09	7.32	6.99	6.94	6.90	6.88	
12	5.59	4.74	4.35	4.12	3.97	3.87	3.79	3.73	3.68	3.63	3.60	3.57	3.52	3.44	3.41	3.38	3.34	3.29	3.28	3.25	3.24	3.23	3.22	3.21	
13	12.25	9.55	8.45	7.85	7.46	7.19	7.00	6.84	6.71	6.62	6.54	6.47	6.35	6.27	6.15	6.07	5.98	5.90	5.85	5.78	5.75	5.70	5.67	5.65	
14	5.32	4.46	4.07	3.84	3.60	3.58	3.50	3.44	3.39	3.34	3.31	3.28	3.23	3.20	3.15	3.12	3.08	3.05	3.03	3.00	2.98	2.94	2.91	2.91	
15	11.26	8.65	7.59	7.01	6.43	6.37	6.19	6.03	5.91	5.82	5.74	5.67	5.56	5.48	5.36	5.28	5.20	5.11	5.06	5.00	4.96	4.91	4.88	4.86	
16	5.12	4.26	3.86	3.63	3.43	3.37	3.29	3.23	3.18	3.13	3.10	3.07	3.02	2.98	2.93	2.88	2.82	2.77	2.76	2.73	2.72	2.71	2.71	2.71	
17	10.56	8.62	6.99	6.42	4.68	3.80	3.80	3.62	3.47	3.35	3.26	3.18	3.11	3.02	2.98	2.93	2.88	2.82	2.77	2.76	2.73	2.72	2.71	2.71	
18	10	4.96	4.10	3.71	3.48	3.14	3.07	3.02	2.94	2.91	2.86	2.82	2.74	2.70	2.67	2.74	2.70	2.67	2.64	2.61	2.58	2.55	2.54	2.54	
19	10.04	7.56	6.55	5.99	5.44	5.39	5.21	5.06	4.95	4.85	4.78	4.71	4.66	4.52	4.41	4.33	4.23	4.17	4.13	4.05	4.01	3.96	3.93	3.91	
20	4.84	3.98	3.60	3.36	3.20	3.01	2.95	2.90	2.86	2.82	2.79	2.74	2.70	2.65	2.61	2.57	2.53	2.50	2.47	2.45	2.42	2.41	2.40	2.40	
21	4.75	3.89	3.40	3.24	3.11	3.00	2.92	2.85	2.80	2.76	2.72	2.69	2.64	2.60	2.56	2.51	2.46	2.43	2.40	2.37	2.36	2.35	2.34	2.34	
22	9.33	6.93	5.95	5.41	5.06	4.82	4.50	4.39	4.30	4.23	4.16	4.05	3.98	3.86	3.78	3.70	3.61	3.56	3.49	3.46	3.41	3.38	3.36	3.36	
23	18	4.67	3.80	3.41	3.16	3.02	2.92	2.84	2.77	2.72	2.67	2.63	2.60	2.56	2.49	2.42	2.38	2.34	2.30	2.28	2.24	2.22	2.21	2.21	
24	9.07	6.70	5.74	5.20	4.86	4.62	4.44	4.36	4.19	4.16	4.02	3.96	3.85	3.78	3.67	3.59	3.51	3.42	3.37	3.36	3.27	3.21	3.16	3.16	

* Reprinted by permission from G. H. Hinde and J. D. Hart, "The Distribution of F^* for the Comparison of Two Estimation Methods," Biometrika, Vol. 57, No. 1, April 1970.

means that differ significantly.

To calculate ANOVA:

- a. Calculate the Total Sum of Squares (SS) $\Sigma(x - \bar{x})^2$

$$\frac{\Sigma x^2}{n} - \frac{(\Sigma x)^2}{n} \quad n = \text{samples}$$

Taking the values from Table 36 gives

$$\begin{aligned}\Sigma(x - \bar{x})^2 &= 879 - \frac{(105)^2}{15} \\ &= 879 - 735\end{aligned}$$

Total sum
of square = 144

- b. Next calculate the sum of squares within groups for the three sites (N_1 , N_2 , N_3)

(1) Dredged Material Site

$$\begin{aligned}\frac{N_1}{\Sigma(x - \bar{x})^2} &= 102 - \frac{(20)^2}{5} \\ &= 102 - 80 \\ &= 22\end{aligned}$$

(2) Downstream Site

$$\begin{aligned}\frac{N_2}{\Sigma(x - \bar{x})^2} &= 263 - \frac{(35)^2}{5} \\ &= 263 - 245 \\ &= 18\end{aligned}$$

(3) Upstream Site

$$\begin{aligned}\frac{N_3}{\Sigma(x - \bar{x})^2} &= 514 - \frac{(50)^2}{5} \\ &= 514 - 500 \\ &= 14\end{aligned}$$

SS within
groups = 54

c. Next, find the sum of squares between groups (SSB)

$$\sum^3 N(\bar{x}_i - \bar{x})^2, \text{ where } \bar{x} \text{ is the mean of all samples (7)}$$

Thus far the difference between Total Sum of Squares and SS within groups is $144 - 54 = 90$. Thus the SS between groups must account for this.

(1) Dredged Material Site

$$\begin{aligned} SSB &= 5(4-7)^2 \\ &= 45 \end{aligned}$$

(2) Downstream Site

$$\begin{aligned} SSB &= 5(7-7)^2 \\ &= 0 \end{aligned}$$

(3) Upstream Site

$$\begin{aligned} SSB &= 5(10-7)^2 \\ &= 45 \end{aligned}$$

This gives us the 90 units of SS mentioned above.

d. This step involves deriving the degrees of freedom. Remembering that

$$\text{Total Sum of Squares} = \text{Within} + \text{Between}$$

Each of these sums has a specified number of degrees of freedom (df); for the total it is $N - 1$, which in this case is $15 - 1 = 14$; the df for within groups is derived as $k(N_i - 1) = 3$ (groups) (5 samples - 1) = $3 \times 4 = 12$; the df for between groups is derived as k (number of groups) - 1 = 2. One now divides the SS within by its df, one gets $(54/12) = 4.5$. This is an estimate of the common population variance independent of the variation in the group means. If one divides the SS between by its df $(90/2) = 45$, one has a second estimate of population variance that is independent of the variation within groups. In ANOVA these independent estimates of population variance are called mean squares.

All of the above is ordinarily tabulated as in Table 38.

Table 38
 ANOVA of Populations of Bivalve sp. 1 from
the Upstream, Downstream, and Disposal Site Station

VARIATION	SUM OF SQUARES	DF	MEAN SQUARES
Between Groups	90	2	45.0
Within Groups	54	12	4.5
TOTAL	144	14	

- e. The final and most critical step is testing the significance of the ANOVA calculations, by finding F.

$$F = \frac{\text{mean square between groups}}{\text{mean square within groups}}$$

From the data in Table 38,

$$F = \frac{45.0}{4.5} = 10$$

To determine whether $F = 10$ is significant at the 5 or 1 percent levels, refer to Table 37 and note where the df of the between groups column (2) runs down and intersects the row marking the df of the within groups (12). It can be seen that $F = 3.88$ for 5% and $F = 6.93$ for 1% significance. Thus, since the value of 10 is larger than the table value of 6.93, one may conclude that the observed value is significant. The null hypothesis to the effect that one obtained random samples from a common (normal) population is rejected. Hence, the means of the samples differ significantly and one is free to attempt to explain what influence, if any, the disposal of dredged material has had on the observed differences.

PRESENTATION OF POPULATION DATA FROM THE MACROEPIFAUNA

Effective numerical sampling of the macroepifauna is more difficult to achieve than it is for the macroinfauna. Nevertheless, many of the marine organisms of commercial value fall in this category, including bottom-feeding (demersal) fishes. The macroepifauna may be defined as those organisms that either live upon the sediment bed or feed upon the bottom and that are over (usually well over) 0.5 mm in length.

Most of the species involved are quite mobile. In addition to demersal fishes, such as the flounder and other flatfishes, common components of the macroepifauna are crabs, shrimps, lobsters, and gastropod mollusks (snails). The obvious commercial value of species that belong in the macroepifauna should not minimize the importance of the macroinfauna in the mind of the reader. This study is dealing with an ecosystem and the macroinfauna and even the smaller meiofauna, to be discussed next, are the principal source of food of the macroepifauna.

The question that must be answered now is what uses can be made of population data derived from sampling of the macroepifauna. It is not as easy to obtain a quantitative sample of this group as it is of the infaunal types. As noted in Chapter IV, the authors recommend use of the beam trawl, which has a more or less fixed aperture of, say, three meters. At shallow sites it is relatively easy to observe by action of the towing wire and accumulator when the trawl has engaged the bottom and when it has left the bottom during retrieval. Knowing the time on bottom and the speed of the ship across the bottom, the distance sampled times the gape of the trawl will give the area sampled. Most towing will be done at a speed of near 1.5 knots (1.5 nautical miles or 2780 meters per hour); thus, a 10-minute tow can be expected to traverse about 460 meters and, multiplying by the 3-meter gape, to sample 1400 m². Obviously these are at best only gross estimates. Some investigators may simply prefer to work with units of effort and normalize the collection data in terms of the number of organisms taken in 10 minutes. Ordinarily three trawl stations are planned for a dredged material site and its contiguous area: one in the site, one downstream, and one upstream. Duplicate trawl hauls are made at each station.

In the macroepifaunal samples, the number of species is not so great that all species cannot be identified; however, it may well be that population data need be taken only for the principal or predominant species in each taxonomic group, such as fishes, crabs, shrimps,

gastropods, etc. These data, then, can be handled statistically in the same way as those obtained for the macroinfauna.

Important comparisons can be made between the hauls inside the site and those outside, individually and jointly. Macroepifaunal data of the population type will be useful primarily to characterize the site and its adjacent areas, but there may well be some monitoring value in the data collected for predominant species. Actually, community parameters may yield some data of greater value to monitoring, as will be discussed shortly.

Some of the macroepifaunal species may be appropriate for the analysis of various pollutants, such as trace metals, aromatic petroleum hydrocarbons, PCBs, and organochlorine pesticides. One frequently encounters strongly held opinions that these larger and more mobile species are unsuitable for such analyses for the reason that if they do wander about and if their tissues have low values of pollutants, it could be that they happened to move into the disposal site just prior to capture and thus could not have acquired a body burden of the toxicant. No one can deny the truth of this possibility for some species. However, there is some evidence that lobsters (*Homerus*) which live near the coast do not move about over a few nautical miles. For example, Templeman (1935) found the average straight line distance between points of release and recapture in the Gulf of St. Lawrence to be less than 5.5 n mi even after being at large for 12 months. Cooper (1970) tagged and liberated 1776 lobsters off Monhegan Island, Maine, and later recovered 99% within 2 n mi of the release point. Apparently this is not true of offshore populations, which undergo extensive seasonal migrations. On the other hand, there is little good evidence that some of the Cancer crabs move about on a regular basis. In fact, after maturing, they may well stay put for considerable periods. Also, some of the demersal fishes actually live in shallow burrows or depressions in the bottom to which they return after feeding forays. Therefore, it is unnecessary to rule out all epifaunal species for pollutant

analyses, but regionally experienced marine biologists both in agencies and universities should be called upon to make the species selection.

PRESENTATION OF POPULATION DATA FROM THE MEIOFAUNA - OPTIONAL

The meiofauna are small, ranging in size from 0.5 mm down to 0.062 mm, which means that the smallest are equivalent to a 4-phi sediment grain (on the boundary between fine sand and coarse silt), and the largest are on the boundary between medium sand and coarse sand. What they lack in size they make up for by the very large size of their populations and in some places by substantial biomass (weight of living tissue). Because the meiofauna may have populations around a million per square meter, one need only take samples of 10 cm² area and 5 cm deep. In some areas the biomass of the meiofauna is equivalent to that of the macroinfauna, depth for depth, in the sediment. Several other characteristics heighten their importance to marine ecosystems and to monitoring and impact evaluation studies. In the first place, many live an interstitial life where they are exposed to pore water. Hence, they are very likely to pick up any dissolved metals and other pollutants. It is now suspected that organisms such as shrimp and bottom-feeding fish depend upon the meiofauna for food and thus enter the food chain to man (Pequegnat and Venn 1979).

Since, in most marine sediments, the nematode worms account for 90% or more of the meiofaunal populations and the harpacticoid copepod crustaceans are second in abundance, it is recommended that counts be made only of these two groups. Because the meiofauna is subsampled from a box core, fairly reliable quantification can be achieved. Two samples covering 10 cm² by 5 cm deep are removed from each box core. Processing the sample for microscopic examination (25x) is not very difficult.

It is recommended that the ratio of population size between harpacticoids: nematodes be derived for each station (Parker 1975; Pequegnat and

Sikora 1977, 1978, and 1979). This can be nicely correlated with sediment parameters because all major factors are sampled from each meiofaunal box core. As might be expected, some aspects of the meiofauna respond dramatically to shifts in the sediment; this is especially true of the nematodes which display increasingly large populations as sand percentages approach and exceed 60%. Since harpacticoid populations respond less to sediment changes than to levels of biologically available organic matter, shifts in the nematode:harpacticoid ratio at individual stations reflect the nature of the environmental change. It is important that the ratio be calculated for changes at individual stations only.

It is recommended that the harpacticoid:nematode ratio be utilized as a definitive parameter for tagging the transport of sediment into the extended impact zone and beyond. It is advisable that sufficient sediment samples be taken per station (minimum of 3) to permit statistical evaluation of the data.

PRESENTATION OF COMMUNITY PARAMETERS

Whereas up to this point interest has been primarily in the numerical abundance or population of certain given species, the concern here is with the species composition of the community of organisms found at sampling stations. Although the community should be thought of as encompassing organisms of all ecological types, macroinfauna, macroepifauna, meiofauna, etc., ordinarily only the data derived by one sampling gear are treated at any one time. Later, if one wishes, all such data can be combined.

SPECIES RICHNESS

The term species diversity has been widely used by biologists in recent years. It is a useful concept in community biology, but it is questionable whether there is any particular value in deriving the so-

called species diversity index for studies of this type. When properly used species diversity has two components, viz., the number of species in a community, called species richness, and the even or uneven way that individuals of the community are distributed among the constituent species. The latter is called equitability. The latter can be understood if it is pointed out that, of two communities that have the same number of species and the same total number of individuals, the one in which the individuals are more evenly distributed among the species would have the higher species diversity index. This is tantamount to saying that when the populations of the species are about equal the equitability is high or, yet another way, highest diversity would be attained if every individual represented a different species. The authors see no particular advantage to calculating a species diversity index over a simple expression of species richness, which is the number of species per sample (unit of area or unit of effort). However, for those who have a special need for a diversity index, the Shannon-Wiener is appropriate, as follows:

$$H = - \sum_{i=1}^s (p_i)(\log_2 p_i)$$

where

H = index of species diversity

s = number of species

p_i = proportion of total sample belonging to the ith species

The basic assumption underlying the desire on the part of some to calculate the species diversity index in a site monitoring or designation program is that it will reveal a great deal about the structure of a community. This is clearly a debatable issue because the index alone does not depend upon what species are present, i.e., it does not deal with the species composition of the community. Species richness determinations together with species composition can be important to site characterization, impact evaluation, and monitoring in general.

The reason that species composition as well as richness is important

relates to energy flow and the fact that energy enters the lower feeding levels and moves through the community by alternate pathways and feedbacks until it reaches the top carnivore. When stresses such as excess heat or toxicants are applied to the species of the community, extra energy must be expended to ameliorate the stress. Those species that cannot meet the demands of stress, that is, who have narrow environmental tolerance, will drop out thereby leaving a smaller number of species or subjecting the community to invasion by (up to then) alien species. Pollution applies stresses; hence, species diversity can be expected to go down or species replacement can occur, or both.

It is not feasible to collect all species of a community, especially with a single type of collecting gear. At best one has only an estimate. The reason for this is simply that there is not the time or resources to produce a true representation of the community. A moment's reflection will reveal that if a beam trawl is being used, individuals are added at a more or less constant arithmetic rate, whereas species are being collected at a decreasing logarithmic rate (Figure 32). Note that at first probabilities are high that each added individual will be a "new" species, but as sampling goes on this rate drops rapidly. A rule of thumb as to the completeness of sampling states that if the sample collected at a station contains any species represented by a single individual, there are yet uncollected species in the same size category.

LOGNORMAL POPULATION DISTRIBUTION

In order to judge the effectiveness of a sampling effort in obtaining a reliable estimate of the actual number of species at a disposal site, one should utilize the lognormal distribution to assess the situation. The curve in Figure 32 suggests that additional sampling can be expected to yield more species, but it is difficult to estimate

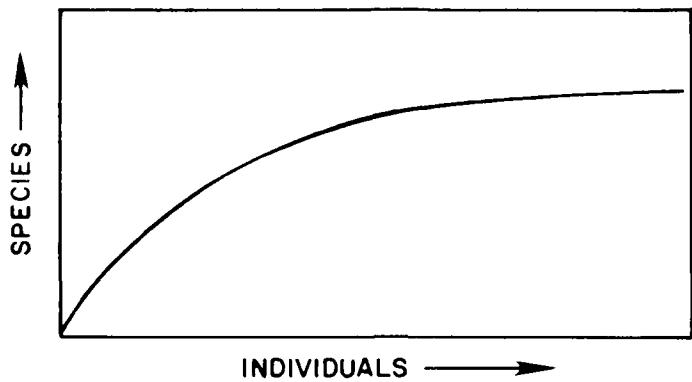


Figure 32. Graph showing the dependence of adequate representation of the total species at a station upon the number of individuals collected. Note the relationship of this parameter to the lognormal curve discussed below.

where one's sampling effort is located on the curve. For this purpose the lognormal distribution is more informative. The basic curve is similar to a normal curve in which the abscissa plots the number of individuals transformed into logarithms to the base 2, and the number of species (not in logs) constitutes the ordinate (Figure 33). In actual practice (in the real world), the lognormal distribution is truncated at the point where species are represented by a single individual (Figure 34). The degree of truncation is proportional to the amount of the universe of species sampled. The area under the extrapolated full lognormal curve gives an estimate of the total number of species N in the theoretical species universe. The area under the truncated sample curve represents the number of species n in the sample. Therefore, the ratio n/N gives the fraction of the species universe in the sample.

From the sample curve, the theoretical population universe can be estimated as

$$N \text{ (tot. no. spp.)} = \sqrt{2\pi}\sigma N_0$$

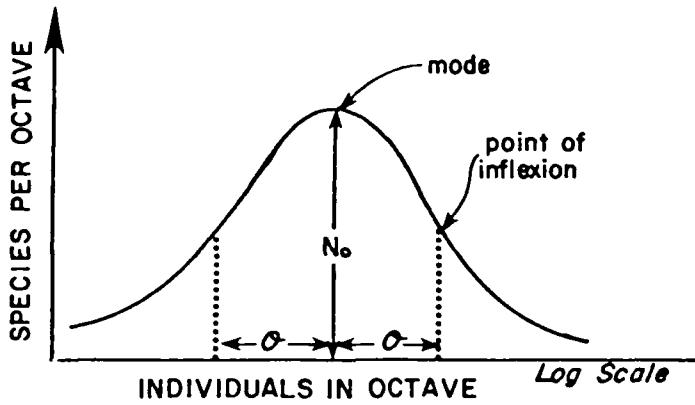


Figure 33. A hypothetical lognormal curve showing the numbers of individuals (logs) in species. N_o = the modal class, and sigma is one standard deviation on each side of the mode. In biological field sampling such a universe is seldom or never obtained (see Fig. 34)

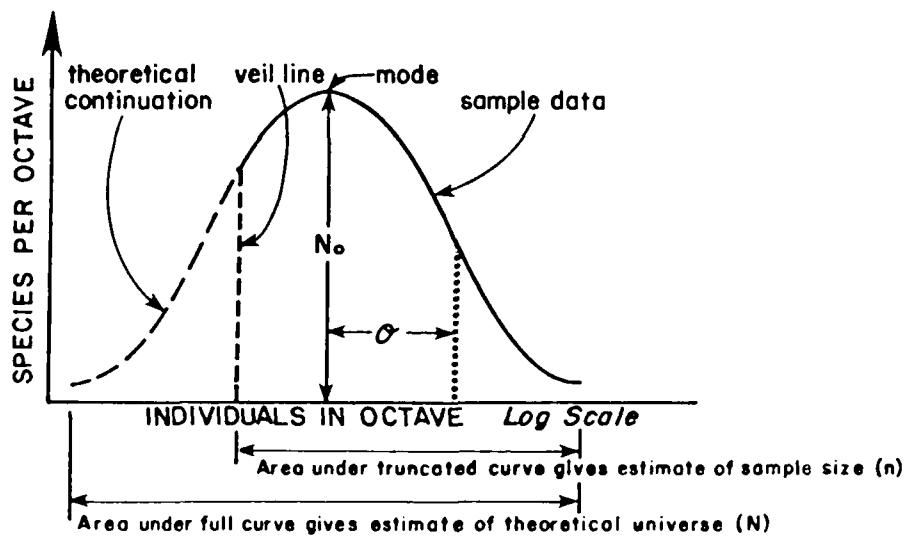


Figure 34. A lognormal curve obtained from field sampling. Since the veil line is to the left of the mode, it is possible to move the curve to the right and thereby estimate the total number of species from which the actual sample was taken

Where

No = no. of spp. in modal octave

σ = logarithmic standard deviation, i.e., distance from the mode to
the point of inflection of the curve.

If the mode falls behind the veil line, a larger sample is required to place the veil line two octaves to the left of the modal octave where the sample lognormal curve is thought to be a fairly accurate representation of the truncated universe curve. Since doubling the size of the sample doubles the number of individuals of the more common species in the sample, this is equivalent to moving every species one octave to the right and withdrawing another octave from under the veil. Thus, given the position of the mode, one can estimate how many times the sample size needs to be doubled before the mode falls two octaves to the right of the veil line. For example, if one beam trawl tow gives a truncated curve with the veil line one octave to the left of the modal octave, then a second tow should place the veil line two octaves to the left. However, it would take 2^2 tows to move the veil line two octaves to the left (Williams 1953).

INDEX OF SIMILARITY

It will be valuable to search for faunal homogeneity among collecting stations by classifying the different sample stations in a simplifying pattern of groups of stations. Both time and space parameters may account for observed differences in community structure of various stations. The changing effect of time may appear as a result of natural seasonal influences, which must be separated from time-dependent stresses of environmental change that produce chronic responses. Since the influence of these stresses, if related to dredged material disposal, will differ depending on the location of the station relative to the point of disposal, spatial considerations become important in accounting for change.

The following method of classifying stations depends upon the fact that stations within groups are more closely related to one another than to those belonging to different groups. The basis for establishing the closeness of relationship will be the species list derived from each station. Thus, the index of similarity overcomes one of the disadvantages of the species diversity index to the effect that it is simply based on the number of species rather than on what they are (Mountford 1962).

Stepwise Calculation of the Index of Similarity

First Step. To arrange stations into groups construct an index that gives numerical value to the similarity between two stations in accordance with the following simplified form:

The index of similarity Z is calculated as:

$$Z = \frac{2c}{2ef - (e + f)c}$$

where

e = number of species in 1st station list

f = number of species in 2nd station list

c = number of species common to both station lists

Suppose that one is attempting to classify the five stations A, B, C, D, and E and that one has calculated the following Matrix of the Indices of Similarity:

	A	B	C	D	E
A	---	0.15	0.23	0.19	0.21
B			0.27	0.29	0.23
C				0.27	0.24
D					0.14
E					---

Second Step. Now from the above table select the highest value, which in this case is 0.29. The pair corresponding to this value, B and D, is combined to form a single group, BD. The indices of similarity between each of A, C, and E and the group BD are then evaluated.

Third Step. Thus, the index between A and the group BD is

$$Z(BD;A) = \frac{Z(AB) + Z(AD)}{2} = \frac{0.15 + 0.19}{2} = 0.17$$

In this way one obtains the reduced matrix

	A	BD	C	E
A		0.17	0.23	0.21
BD			0.27	0.19
C				0.24

The highest value is 0.27 between C and BD; therefore, BD and C are combined.

Fourth Step. The indices of similarity between A and E and this new grouping are

$$Z(BCD;A) = \frac{Z(AB) + Z(AC) + Z(AD)}{3} = \frac{0.15 + 0.23 + 0.19}{3} = 0.19$$

and

$$Z(BCD;E) = Z(EB) + Z(EC) + Z(ED) = \frac{0.23 + 0.24 + 0.14}{3} = 0.20$$

.

The reduced matrix is

	A	BCD	E
A		0.19	0.21
BCD			0.20

The highest value is between A and E; hence, they are combined.

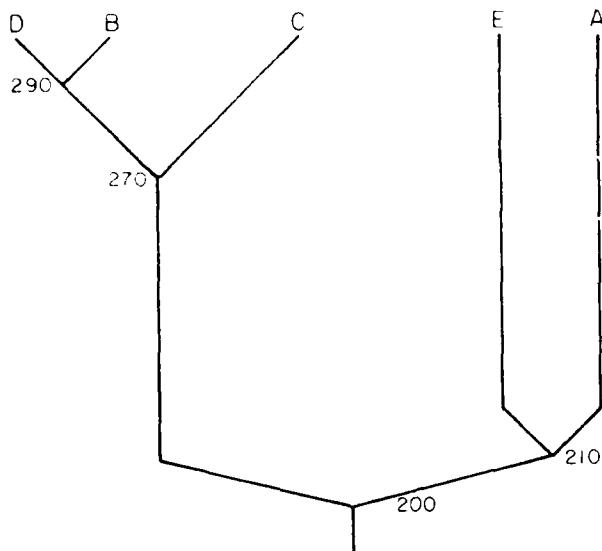
Fifth Step. The index of similarity between AE and BCD is:

$$Z(AE;BCD) = Z(AB) + Z(AC) + Z(AD) + Z(EB) + Z(EC) + Z(ED) =$$

$$\frac{0.15 + 0.23 + 0.19 + 0.23 + 0.24 + 0.14}{6} = 0.20$$

	AE	BCD
AE		
		0.20

Sixth Step. At this point one is ready to display the clustering of stations as a branching graph called a dendrogram. The levels of branching are determined by the values of the indices of similarity ($\times 10^3$).



Note that BCD make one major branch and AE make the other. Within the group BCD, the largest index of similarity is between B and D, hence, one is shown branching off of the other.

This might reflect an actual set of five sampling stations in and adjacent to a dredged material disposal site, where stations E and A are within the site and C is in the impact zone and D and B are upstream stations. It is thought that this station or site clustering technique may assist in describing quantitative differences in faunal homogeneity between natural and disturbed benthic faunal communities or assemblages.

APPLICATION OF CRITERIA FOR DATA INTERPRETATION

ECOSYSTEM: ENVIRONMENTAL UNIT OF CONCERN

Even in its simplest form the ecosystem includes all of the biological and nonbiological components of the environment, such as water, sediments, temperature, salinity, etc., and their interactions. In each environment the prevailing condition of the system has been produced by

dynamic interaction among its physical and biological components, processes, and outside forces. If any one of these biological components is changed, say, by addition of a significant stress, a new balance is reached in the system. Each ecosystem possesses those species and biotic communities that are adapted to the specific environment and are therefore successful in that environment. Pollutants will modify the specific environment, adding stresses, and may eliminate susceptible species. In some instances, unwanted species may be nurtured. If the stresses are severe, the system will become less productive and of less value to man. If stresses are both severe and persistent, disruption of the entire ecosystem may occur. Dredged material does stress the marine environment, but in general few of the stresses are severe and persistent, except perhaps at a point of repeated disposal. The objective of the following discussion is to provide guidelines for stress evaluation.

ECOSYSTEM IMPACTS OF DREDGED MATERIAL

Effects that dredged material can have on the system are to:

- a. increase turbidity for short periods in surface waters and for longer periods in deeper layers, thereby reducing inputs of solar energy, which will result in some reduction of primary production by phytoplankton and fixed plants; this may also injure respiratory surfaces of some animals and interfere with olfaction
- b. increase the concentrations of some nutrients and of organic matter, resulting in population increases in some species; ordinarily these species will be undesirable, and their population explosion will itself stress other species
- c. reduce the availability of some nutrients by increasing sedimentation with accompanying sorption
- d. eliminate some species by adding a toxic material, thereby increasing chances of reduction of community diversity
- e. facilitate bioconcentration or bioaccumulation of toxic materials present in low levels in dredged material

- a. overthrow the biomass balance of the system by either reducing abundant species or by removing carnivores thereby permitting prey species populations to expand rapidly
- b. reduce species diversity

USED FOR BENCHMARK DATA

The importance of establishing a reliable set of benchmark or baseline data on the benthic fauna in the initial ocean surveys is demonstrated by the species diversity parameter in its simplest form, namely, the number of species in the community. When stresses are applied to the organisms of the community, energy will be spent to counter the stress. The early effects of this expenditure will be to overwhelm and remove species with narrow tolerances. Then, when the point is reached involving survival of the whole community, it will fall off rapidly. Thus, the impacts of even low-level stresses on an already stressed community will result in an apparent loss of tolerance.

BIOCONCENTRATION, BIOACCUMULATION,

Larger accumulations of toxicants in the body of a dominant species of a community affect the entire community material than in individuals from the community. Such a state of bioconcentration may exist. This uptake may result in either acute or chronic responses. The path of entrance of the pollutant may depend on the selection of some aspects of the survey. A recent study (MacCleek et al., 1979) indicates that the principal route for the uptake of many toxic chemicals by finfish and shellfish is directly from the water through the gills and to the epithelial surfaces, such as in the gut, rather than through dietary sources. The direct process is called bioconcentration, as distinct from bioaccumulation which includes both the dietary and direct processes.

Exogenous pollutants that may be carried by dredged material to the marine environment are toxic metals, Aroclors (PCBs), high molecular

weight hydrocarbons, and chlorinated hydrocarbons such as aldrin, dieldrin, endrin, kepone, DDT, etc. When concentrations of these compounds reach high enough levels in the body, death will ensue. The rate at which this uptake occurs depends in part upon the species of animal involved and upon the concentration of the compound in the environment. More frequently than not the environmental manager has more data upon the concentrations of pollutants in the physical environment than in the biota. For that reason, the discussion to follow will deal with environmental concentrations rather than biotal. This is all the more appropriate in light of recent evidence regarding the occurrence of biomagnification.

Trophic level biomagnification, the process by which tissue concentrations of bioaccumulated chemical residues increase as these materials pass up a food chain, is not as common an occurrence as once thought from the original findings for DDT. Macek et al. (1979) believe that one can screen compounds for their potential of causing significant biomagnification by determining the rate at which the organism can rid itself of body burdens (called depuration) when placed in uncontaminated water. DDT is used as the calibrating compound for tests to show that fish require an average of about 140 days to eliminate 50% of their body burden of this compound. On the other hand, only from 14 to 42 days are required for depuration of PCBs and kepone. Whereas DDT concentrations are magnified by food chain transfers, it appears that PCBs, kepone, and other easily excreted compounds are not. Actually, then, the environmental manager should concentrate attention on obtaining as much information as possible on the concentration of toxic compounds in the ambient waters and, to a lesser extent, in the sediments. However, to assess the development of chronic effects from the accumulation of initially low levels of pollutants, the assay of appropriate metabolic enzymes may be the method of choice.

GUIDELINES AND CRITERIA FOR INTERPRETING SIGNIFICANCE OF POLLUTANT CONCENTRATIONS

Metals

Cadmium. This Annex I metal is generally present at concentrations of about 0.15 parts per billion (ppb) in seawater. It is preferentially accumulated by some marine organisms. The finfish Fundulus heteroclitus exhibits acute effects of cadmium at 50 ppm in water (Gardner and Yevich 1970). The oyster Crassostrea virginica shows chronic effects when exposed to 0.1 ppm of Cd in seawater (Pringle et al. 1968).

U. S. Environmental Protection Agency (1976a) water quality criteria call for no more than 5 ppb in marine waters. Effects on organisms of concentrations above that level in their tissue may be evaluated by analysis of the metabolic enzyme catalase (see Chapter VII, page 196). If catalase levels in organisms exposed to cadmium at the DM disposal site are more than one standard deviation below the mean of control organisms, it is possible that chronic responses may develop.

Mercury. This Annex I metal is generally present at concentrations of about 0.05 to 0.19 ppb in seawater. Mercury compounds such as mercuric chloride, ethyl mercury phosphate, and alkyl mercury at levels as low as 1 ppb have been demonstrated to have deleterious effects upon fish (Schweiger 1957), phytoplankton (Ukeles 1962), kelp (Clendenning and North 1960), and clam larvae (Woelke, 1961).

U. S. EPA (1976a) water quality criteria call for no more than 0.1 ppb in seawater to protect marine life. Effects on organisms of concentrations above that level in their tissues may be evaluated by analysis of the metabolic enzyme catalase (see Chapter VII, page 196). If

catalase levels in organisms exposed to mercury at the BM disposal site are more than one standard deviation below the mean of control organisms, it is possible that chronic responses may develop.

Petroleum Hydrocarbons

Most hydrocarbons in the environment originated either in plants and animals, or they are petroleum derivatives. A number of parameters may be calculated from gas chromatograms of extracts of environmental samples which may allow differentiation of biogenic from petroleum hydrocarbons with a fair degree of certainty. The most useful of these are described below (Farrington and Madeiros 1973).

Total aromatic hydrocarbon concentrations, for example, would be expected to be higher in a sample containing petroleum than in a noncontaminated one. Of course, aromatic content differs among petroleums.

The presence of an unresolved complex mixture in the chromatogram may also be indicative of petroleum. Unresolved complex mixtures that occur naturally in extracts of some organisms are usually seen in a different region of the chromatogram and are easily distinguished from such mixtures in extracts containing petroleum.

The ratio of the concentrations of n-C₁₇ and pristane is an indicator of oil degradation after a major spill. It is of little value for baseline studies because of seasonal and individual variation in biota. High pristane levels relative to n-C₁₆ may reflect the presence of petroleum.

In mixtures of biogenic hydrocarbons, compounds with odd-numbered carbon chains predominate in the range from n-C₁₄ through n-C₁₆, which is in contradistinction to petroleum fractions. From n-C₂₀ through n-C₃₆, however, biogenic mixtures are not distinguishable from petroleum.

hydrocarbons on that basis. That information is usually expressed as the carbon preference index (CPI) from the C₁₄-C₂₀ range (CPI₁₄₋₂₀). It is calculated as follows:

$$\text{CPI}_{14-20} = \frac{\frac{\sum_{n=19}^{} \text{HC}_{\text{odd}}}{n=15}}{\frac{\sum_{n=20}^{} \text{HC}_{\text{even}}}{n=16}} \quad \frac{\sum_{n=19}^{} \text{HC}_{\text{odd}}}{n=15} \quad \frac{\sum_{n=18}^{} \text{HC}_{\text{even}}}{n=14}$$

A CPI₁₄₋₂₀ greater than 2 usually indicates a biogenic source.

Petroleum products vary considerably in their toxicities to marine animals. The degree of toxicity of an oil is directly correlated with its content of aromatic hydrocarbons. Comparisons of the relative toxicities of different petroleum products and the sensitivity to oil of different marine species are difficult to extract from the literature because a variety of methods were used to introduce petroleum into the water and often its concentration in the aqueous phase of the exposure medium was not measured. The acute chemical toxicity of petroleum to marine animals is probably due primarily to those components of the oil which go into solution in the water column. The solubility of aromatic hydrocarbons in water decreases with increasing molecular weight. Hence, much of the acute toxicity of most crude and refined oils can be attributed to the naphthalenes and, to a lesser extent, to the benzenes present. Thus, 50% of the grass shrimp Palaeomonetes pugio were killed in 96 hours (96-hr LC₅₀) by 27 ppm of benzene and only 2.4 ppm of naphthalene (Neff et al. 1975). Marine larvae are susceptible to petroleum pollutants at concentrations as low as 0.1 part per million (Moore and Dwyer 1975). Sublethal effects of oil pollution can occur at concentrations between 10 and 100 parts per billion (Mironov 1970).

Marine organisms are capable of accumulating petroleum products in their tissues, especially in their body fat. For instance, the clam Rangia cuneata when exposed to 0.071 ppm of naphthalene for 24 hours accumulated 0.43 ppm in its tissues (Neff et al. 1975). It was noted that the clam was able to depurate 66% of its body burden of naphthalene in 24 hours.

In general, if an organism that has been collected on or around a DM disposal site has any aromatic hydrocarbon in its tissues at or above 8 ppm, it is quite likely to show some signs of chronicity. Using an application factor of 0.01, one should consider modifying dumping practices at least temporarily if tissue levels of 0.08 ppm are found in one or more important species. An additional factor is the possibility even lower concentrations of some oil compounds can cause tainting of finfish and shellfish.

The metabolic enzyme cytochrome P-450 is very responsive to the uptake of petroleum hydrocarbons by marine organisms. If the P-450 levels in exposed animal tissues rise one standard deviation above those of the controls, it can be expected that chronic effects will develop unless the organism is able to unburden itself in a relatively short time.

Polychlorinated Biphenyls (PCBs)

Duke et al.(1970) were among the first investigators to report the appearance of significant amounts of PCBs in the marine ecosystem. Since PCBs are highly toxic, man-made contaminants of recent times, it is essential that their escape into the marine environment be curtailed by effective means. This control is especially important for PCBs because they can be accumulated to lethal levels by some freshwater and marine organisms even when concentrations are very low in ambient waters. For example, chub (fish) in the Great Lakes were found to contain tissue levels of 5 ppm of PCBs, whereas the concentrations in the ambient lake waters seldom exceeded 0.01 ppb. This is an excellent example of bioaccumulation. Data generated by Duke (1974) and Schimmel

(1974) indicate that the accumulation factor for PCBs (i.e., the multiplier of test water concentration to reach level in the organism) ranges between 10^2 in oysters to $2.5 - 3.7 \times 10^3$ in various species of shrimps, crabs, and fish. It is this high degree of bioaccumulation that justifies U.S. EPA's (1976a) PCB water quality criterion of only 0.001 ppb to protect both freshwater and marine life.

One can illustrate the reasoning that supported the establishment of this criterion by examining part of the life-cycle of the grass shrimp (*Palaeomonetes pugio*). Bioassay results show that the 96-hr LC₅₀ of adults in water containing Aroclor 1254 in water ranges around 64 ppb, whereas that of juvenile shrimp is about 7.8 ppb. Larval shrimp, however, will develop normally between 0.1 and 3 ppb but not above (National Science Foundation 1974). Thus, if one follows the rule that the maximum concentration of a given toxic chemical in water should not exceed one-hundredth of the LC₅₀ values, then truly safe levels for the entire life-cycle would have to range between 0.01 and 0.001 ppb PCB in solution in the water.

Although mortality in bioassays provides insights as to the actual effect of the accumulation of PCBs on the consuming organism, another approach appears to be needed to assay sublethal accumulations that may lead to chronic impairment of an organism's health. It is suggested that an evaluation of potential chronicity can be obtained by comparing the level of the enzyme ATPase in the tissues of an animal exposed to marine waters containing PCBs with levels in controls of the same species. A change of 25 percent or more from the controls in the mean values of the disposal-area organisms should be considered a signal to monitor the trend.

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PROCEDURAL GUIDE FOR DESIGNATION SURVEYS OF OCEAN DREDGED MATER--ETC(U)
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APPENDIX A

CHIEF SCIENTIST'S GUIDE FOR AT-SEA OPERATIONS

(A Condensation of Certain At-Sea Activities to be Used as a Supplement to the Rest of the Report. For Sampling Details Refer to Chapter VI.)

PLANS PRIOR TO THE SURVEY CRUISE

CHECKLIST OF PRECRUISE RESPONSIBILITIES

ITEM 1. Assign to individual members of the survey party responsibility for the following:

- a. Having adequate sample holding bottles, vials, and foils aboard, along with labels, tapes, and marking pens. Also, all preservatives (formalin, alcohol, hexane, etc.) should be aboard in ample quantities and stored safely.
- b. Seeing to it that all sampling equipment (except the STD and current meter) is aboard: transmissometer, grabs, box corers, trawls, and plastic and stainless steel coring tubes for sub-sampling sediment. Also, see to it that the grab and box corer are in good working order. Extra trawl bags should be available and a second box corer is advisable.
- c. The STD and current meter are special cases. The probes of the STD should be checked and calibrated, especially conductivity and dissolved oxygen. The current meter and STD cables can be damaged - they should be checked for continuity.
- d. Assign responsibility to one person (he may have one or more helpers) for seeing that every sample is properly labeled and stored.

ITEM 2. The Chief Scientist should discuss survey plans with the ship's Master. It should be understood that the Master has the last word regarding safety of ship and personnel and that the Chief Scientist can order the course of the ship within the safety limits. All explosive and/or flammable chemicals brought aboard the ship should be stored

and handled under the auspices of the Master. The Chief Scientist should instruct his party, if necessary, that they should seek the cooperation of the ship's crew but not expect them to work as members of the survey party unless such assistance has been agreed upon by the Master.

ITEM 3. Prepare a station list including the number of activities at each station for the Master. Indicate which stations are anchor stations and the duration of activities. On some of the longer anchor stations it may be advisable to shut the engines down, especially if it is a sizable ship.

ITEM 4. The Chief Scientist should plot on his hydrographic chart the location of any critical areas (spawning grounds, shellfish beds, or human amenities) prior to departure, since this information must come from the literature or conversations with local fishermen. This will become important after determination of the bottom current as to placement of the upstream and downstream sampling stations. A guide as to what critical distances are involved might be as follows: if the current is flowing at a rate of 1 knot (1 nautical mile or 1852 m in an hour) and 4 hours are allowed for mixing, as in the criteria on ocean dumping, the fine materials would travel no more than 4 n mi (4.6 statute miles) in this time. Thus, any amenities 5 or more n mi away are probably not matters of concern.

CARRYING OUT THE SURVEY CRUISE

STEPS TO BE FOLLOWED THROUGHOUT THE CRUISE

STEP 1. The Chief Scientist must assist the Master in locating the site. When this has been done, start Step 2.

STEP 2. Immediately run fathometer traces across the site to obtain needed information on bathymetry. Use these traces in arriving at the following decisions.

Decisions to be Made at This Point

ITEM A. Set the location of the two within-site sampling stations. It is advisable that the trawl stations not cross the box corer stations, although they may be adjacent.

ITEM B. Locate the point, probably between the above two stations, where the speed and direction of the bottom current should be determined.

STEP 3. Proceed to the current meter station and anchor the ship.

Use fore and aft anchors, if possible.

STEP 4. Immediately take an STD profile for temperature, salinity, and, if possible, dissolved oxygen. Note the presence or absence of a thermocline or halocline. If present, determine speed and direction of the current above and below the discontinuity, for this is a two-layered system.

STEP 5. Take the water samples (upcurrent side of the ship) required for:

- a. Dissolved Hg
- b. Dissolved Cd, Pb, and Cu
- c. Chlorinated hydrocarbons
- d. Petroleum hydrocarbons

Then take a vertical haul with the transmissometer.

STEP 6. Take a current meter reading at positions indicated above for a period of at least 30 minutes. Attempt to estimate period of tidal cycle during measurement (refer to tide chart). The bottom current should be measured at 1.5 m above the bottom (to avoid the much slower boundary layer).

STEP 7. During the period of current measurements, observe the wind, noting particularly its direction (remember for wind currents the observer faces into the wind and reads direction; for water currents the direction is that of the flow, i.e., the observer faces downcurrent). Some estimate of its speed would be helpful, especially if this is correlated with sea state. White caps on waves appear at around 10-12 knots (1 knot = 1.15 mph).

STEP 8. Note the wave height and direction, particularly in relation to the wind. The wave period can be timed by noting the interval in seconds between the passing of successive crests or troughs at the ship.

STEP 9. Up anchor and proceed to the near downstream within-site station and anchor (a single point is acceptable here) preparing for sampling of the macrofauna (and meiofauna) with a box corer or Smith-McIntyre grab.

- a. Obtain the first box core sample. If the sediment is sandy, it will probably be necessary to add weights to the corer. The corer should penetrate deeply enough into the sediments that the core length is great enough to prevent supernatant water from leaking out around the sides of the core. If this happens, reject the core and try again.
- b. If the sample is satisfactory, immediately shove the two plastic core tubes for meiofauna into the sediments and two each for sediment before draining off any water. Now siphon off excess water with a rubber hose. Next take samples for trace metals. Now remove the samples for PCBs and pesticides and petroleum hydrocarbons with stainless steel tubes or other similar devices. Then remove sediment and metal tubes and finally the meiofaunal tubes.

Decisions to be Made at This Point

ITEM C. Set the locations of the two downstream stations (0.5 and 4.5 n mi). If there is a critical area downstream

and the bottom current is over 0.5 knots, then the two stations should be on a line between the most frequently dumped upon part of the site and the critical area.

ITEM D. Now set the locations of the two upstream stations. If the current was found not to be very strong, it may be advisable to use only one upstream station, say, 0.5 n mi from the site, and shift the second station the same distance between site boundary and shore. If there are two downstream critical areas, then by all means shift the one upstream station on a line toward it.

- c. Now take the five (5) box cores for the macroinfauna. Again reject samples if the supernatant water runs down the side while the corer is being hoisted aboard. It will be advisable to take a sediment sample from the first two cores.

Place the core in a sample-holding box and remove only the top 15 cm of the core and place in a plastic bucket. If the samples can be sieved in 24 hours, no preservative is necessary as long as they are kept cool. If they cannot be sieved within hours, they must be preserved in formalin.

- d. Take an STD profile. Be sure to note time and tide. Note wind and wave conditions.

STEP 10. Up anchor and proceed to the far downstream outside-the-site station. Repeat parts a, b, c, and d of Step 9.

STEP 11. Up anchor and proceed to the near downstream outside-the-site station and repeat parts a, b, c, and d of Step 9.

STEP 12. Up anchor and proceed to the upstream within-site station and repeat parts a, b, c, and d of Step 9.

STEP 13. Up anchor and proceed to near upstream outside-the-site station and repeat parts a, b, c, and d of Step 9.

STEP 14. Up anchor and proceed to far upstream outside-the-site station and repeat Step 12. If the decision was made to move this station to the line between site and shore, move there and sample. Meanwhile, the beam trawl should be rigged for immediate use.

When the last box corer sample is aboard, rig the winch, sheaves, and line for trawling.

Note: If the decision had been made to stay on anchor overnight at any of the sites sampled in Steps 9-14, then current meter readings should be taken every 3 hours through the night.

STEP 15. Beam trawl station. Carry out the three beam trawls in order from upstream, across the site, and downstream.

- a. Upstream: start at the far (distal) station and trawl on the line toward the proximal upstream station. Keep trawl on bottom for 10 minutes at a speed between 1 and 2 knots.
- b. Site Station: start at the upstream line and move on a line toward the proximal downstream station. Keep on bottom 10 minutes even if downstream boundary of the site is crossed.
- c. Downstream: start at the proximal station and trawl toward the distal station. Keep trawl on bottom for 10 minutes at a speed between 1 and 2 knots.

The beam trawl samples must provide specimens for several analyses; hence, they must be handled with considerable care, as follows:

- a. When the sample is airborne and before it is brought aboard to the deck, rinse as much sediment as possible from the cod end.
- b. After rinsing, lower the cod end over a large plastic tub with low walls (a child's plastic wading pool serves well) and pull the release cord on the bag.
- c. Take a picture of the spilled sample and immediately select specimens for metal analyses (plastic bag), PCB analyses (hexane-rinsed foil), and petroleum hydrocarbons (hexane-rinsed foil).
- d. Then sort the sample into principal groups and place in plastic bags with preservative. Place all the plastic bags in a pail (plastic) with tight-fitting lid.

STEP 16. If time is available, it would be advisable to take one more STD profile and current meter station.

APPENDIX B

BASIS FOR ESTIMATES OF SURVEY COSTS

TIME REQUIREMENTS

FOR SAMPLING

Any estimate of the hours or days of sampling required to prepare for, carry out, and complete the recommended site-designation survey must be based in part upon the size and depth of the preponderance of sites. Generally such sites can be surveyed from a day boat of moderate size. This means that the boat will dock each night and the survey party will bunk ashore. Charter costs for day boats are substantially lower than for more conventional oceanographic craft so that worthwhile savings can be obtained. Moreover, there is a real advantage in having a member ashore at all times to sieve samples, especially the bulky macrofaunal samples. It is recommended that four members of the 5-man team occupy posts on the boat, as will be discussed later.

Basing these estimates on the day boat and a 5-man survey party, it should be possible to survey a site very effectively in 24 hours, as follows:

Box coring	12 hr
Bathymetry	2 hr
STD	2 hr
Current meter	2 hr
Trawls	2 hr
Eating	1.5 hr
Water samples	1 hr
Incidental observation	1 hr
Time slippage	<u>0.5 hr</u>
	24 hr

Even though the actual sampling could be accomplished in 24 hours, it is recommended that the survey (on a day boat) be carried out in three 8-hour days. In the author's experience, it has been found that the serial days often permit better insights into current and circulation patterns and more efficient tying together of loose ends of sampling and recording of notes.

FOR PREPARATION

Preparation time computed here refers only to the time spent mobilizing (mob) the ship, including getting all samples and sampling/holding materials aboard, and the time needed to demobilize (demob) the ship. Preparatory time needed by the survey party at the home base is not calculable and, indeed, for these purposes is not relevant. Mob and demob time is important because it is one of the determiners of the duration of the ship lease. In the author's opinion, one should allow at least one survey party and one ship lease day for these necessary functions.

FOR SHIP LEASE

The minimum duration of the ship lease will be four days, as follows:

Sampling	3 days
Mob & Demob	<u>1 day</u>
	4 days

Another factor which may extend this time is that required for steaming from the ship's home dock to the survey dock. This may be negligible when the two docks are in the same harbor, but in other cases one or possibly two days will have to be added. Note also that no time has been added for weather contingencies. High wind and swell can make sampling of shallow sites impossible. Balanced somewhat against this time need, however, is the fact that if more than one site is to be surveyed from the ship, mob and demob time can be amortized among

them. All things considered it is probably best to allow a range of 5-6 ship-days per site. If a more conventional sleep-in vessel is used, the number of days can be reduced, assuming a 24-hour schedule is kept. Such a vessel will have to be used on deeper sites. Even so, not much savings of time will be effected because more stations and more water column samples will have to be taken. Moreover, additional survey party members will have to be added.

COST REQUIREMENTS

FOR THE BOAT

The cost of day boat lease per site is likely to range around \$6,000 including fuel.

FOR MANPOWER

SAMPLING

A 5-man survey party is recommended when a day boat is used. Four members will carry out the at-sea sampling, and the fifth member will carry out preliminary processing of samples at the dock. In the author's opinion, the survey party should have the following make up:

- | | |
|-----------|--|
| Shipboard | 1. Chief Scientist - oceanographer
2. Oceanographer - biological oceanographer (fishes)
3. Head Technician - biological oceanographer (invertebrate)
4. Technician - chemical or geological oceanographer |
| Land | 5. Asst. Technician - biologist |

The first two should have an advanced degree and have 5-10 years experience, including leadership of oceanographic cruises. In addition, some allowance must be made for visits and early participation of the Project Director in the field survey. This should be a senior person.

Allowing as much as two days for travel time, the manpower time cost of the field aspect of the survey is likely to run around \$5,000 including overhead.

SAMPLE ANALYSIS IN THE LABORATORY

The cost here should be estimated from the usual charge for analyzing each type of sample and multiplying by the number of samples that must be analyzed. This shall be done and then the final cost estimate shall be calculated on the basis of the typical site (40 days required for lab work). A typical site may range in size from 1 to 3 n mi² and is situated in water no more than 20 m deep. Larger or deeper sites may cost more.

Estimate Based 6 Stations Each of Two Seasons

	<u>Price Range</u>	<u>Number of Samples</u>	<u>Total Cost*</u>
a. Water Column (per sample)			
Dissolved metals			
Cadmium & lead	\$ 50-60	4	\$ 200-240
Mercury	25-30	4	100-120
Pesticides and PCBs	150-175	4	600-700
High molecular weight (HMW) hydrocarbons (aliphatics & aromatics by gas-liquid chromatography (GLC)	275-290	4	900-1,160
b. Sediments (per sample)			
Grain size & human debris	35-40	36	1,260-1,440
Metals			
Cadmium & Lead	50-60	12	600-720
Mercury	25-30	12	300-360
Pesticides & PCBs	200-225	12	2,400-2,700
HMW hydrocarbons (aliphatics & aromatics GLC)	275-290	12	3,300-3,480
Oil & grease	25-35	12	300-420
Total organic carbon (TOC)	25-35	12	300-420
c. Biota			
Nematode/harpacticoid	100-125	24	2,400-3,000
Macroinfauna	175-250	60	10,500-15,000
Macroepifauna	100-125	6	600-750
Metals (2 species, 3 locations)			

* Cost estimates prepared in September 1979.

Cadmium & lead	80-100	12	960-1,200
Mercury	45-60	12	540-720
Pesticides & PCBs	200-225	12	2,400-2,700
Enzymes (3)*	35-55	30	1,050-1,650
Adenylate Energy Charge*	15-30	30	450-900
			<hr/>
*(not in site characterization survey)			\$29,160-37,680
			(27,660)(35,130)

REPORT PREPARATION

The report should be prepared by the senior scientist, one assistant, and a secretary. Use of a computer can greatly simplify data management.

It is estimated that 20 days will be required and that the cost including overhead would range around \$7,000.

OTHER COSTS

Travel. 1000-mile round trip.

Transport	\$1,000
Per diem	<u>1,125</u>
	\$2,125

Travel transport is reduced if more than one site is done from a geographic location.

Materials & Supplies.

Field, laboratory	\$1,500
-------------------	---------

Fee. Fees for consulting firms center around 10% of total costs.

Summary Two Visits

Ship	\$12,000
Manpower (field)	10,000
Lab Analyses	35,130
Report	7,000
Travel	4,250
Materials	<u>1,500</u>
	\$69,880
Fee (10% of Total)	<u>6,990</u>
	\$76,870

Cost estimates prepared in
September 1979.

APPENDIX C

LIST OF EQUIPMENT SUPPLIERS

Equipment manufacturers and their respective products are listed in Table C-1. This table is a partial list and in no way reflects on the quality or preference in selection of equipment or their respective manufacturers. It is the responsibility of the procurement officer or his consultant to determine which manufacturer's product is best for his particular application.

TABLE C-1. MANUFACTURERS OF SAMPLING EQUIPMENT
(ADAPTED FROM INTERSTATE ELECTRONICS CORPORATION 1979)*

Product	Manufacturer
STD - CTD	Environmental Research and Technology, Inc. Concord, MA
	Guideline Instrument, Inc. Elmsford, NY
	Neil Brown Instrument Systems, Inc. Falmouth, MA 02534
	Hydrolab Austin, TX 78766
	Inter-Ocean Systems, Inc. San Diego, CA 92123
	Martek Instruments, Inc. Newport Beach, CA 92600
	Plessey Environmental Systems, Inc. San Diego, CA 92138
Dissolved Oxygen Probe	Environmental Research and Technology, Inc. Concord, MA
	Horiba Instruments, Inc. Irvine, CA

*See References at the end of the main text.

Table C-1. (continued)

Product	Manufacturer
Dissolved Oxygen Probe (cont.)	Hydrolab Austin, TX 78766 Inter-Ocean Systems, Inc. San Diego, CA 92123 Martek Instruments, Inc. Newport Beach, CA 92660 Neil Brown Instruments, Inc. Falmouth, MA 02534 Plessey Environmental Systems San Diego, CA 92138
Rosette Water Sampler	General Oceanics Miami, FL 33127
Water Bottles	General Oceanics Miami, FL 33127 Go-Flo Water Bottles Niskin Water Bottles Segmented Water Bottles Wildlife Supply Co. Saginaw, MI 48602 Fjarlie Water Bottles Kemmerer Water Bottles Van Dorn Water Bottles Inter-Ocean Systems San Diego, CA 92123 Nansen Water Bottles Kahl Scientific Instruments El Cajon, CA 92022 Nansen Water Bottles

Table C-1. (continued)

Product	Manufacturer
Water Bottles (cont.)	Hydroproducts San Diego, CA 92112 Van Dorn Water Bottles Benthos, Inc. North Falmouth, MA 02556 Blumer Organic-Free Water Bottles Blumer Large-Volume Water Bottles
Box Corer	Modern Products Box 461 Bryan, TX 77801 Grey-O'Hara Box Corer Ocean Instruments San Diego, CA 92110 Spade Box Corer
Grab Samplers	Benthos, Inc. North Falmouth, MA 02556 Boomerang Grab Van Veen Grab Hydro-Products San Diego, CA 92112 Shipek Grab Ocean Instruments San Diego, CA 92110 Van Veen Grab Wildlife Supply, Inc. Saginaw, MI 48602 Ponar Grab

Table C-1. (continued)

Product	Manufacturer
Grab Samplers (cont.)	<p>Kahl Scientific Instrument Co. El Cajon, CA 02022</p> <p>Box Sediment Grab Dietz-Lafond Bottom Grab Orange Peel Grab Screen Top Grab Smith-McIntyre Grab Van Veen Grab</p>
Dredges	<p>Benthos, Inc. Falmouth, MA 02556</p> <p>Benthic Rock Dredge Pipe Dredge</p> <p>Ocean Instruments San Diego, CA 92110</p> <p>Benthic Rock Dredge</p> <p>Wildlife Supply Co. Saginaw, MI 48602</p> <p>Ekman Bottom Dredge Emery Pipe Dredge Petersen Dredge</p> <p>Kahl Scientific Instruments Co. El Cajon, CA 92022</p> <p>Benthic Rock Dredge Birge-Ekman Dredge Petersen Dredge</p>
Trawls	<p>Maranovich Trawl Company Biloxi, MS 39533</p> <p>James Willis, Net Maker Morro Bay, CA 93442</p>
Nephelometer Transmissiometer	Montedoro/Whitney San Luis Obispo, CA 93401

Table C-1. (continued)

Product	Manufacturer
Nephelometer Transmissiometer (cont.)	Martek Instruments, Inc. Newport Beach, CA 92660 Hydro-Products San Diego, CA 92112
Current Meter	General Oceanics, Inc. Miami, FL 33127 Hydro-Products San Diego, CA 92112 Endeco Marion, MA 02738 Inter-Ocean Systems, Inc. San Diego, CA 92123

APPENDIX D

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Pequegnat, Willis E

Procedural guide for designation surveys of ocean dredged material disposal sites / by Willis E. Pequegnat ... [et al.], TerEco Corporation, College Station, Texas. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1980.

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 2. Marine environment.
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